

Measurement of the Strange-Antistrange Asymmetry at NLO in QCD from NuTeV Dimuon Data

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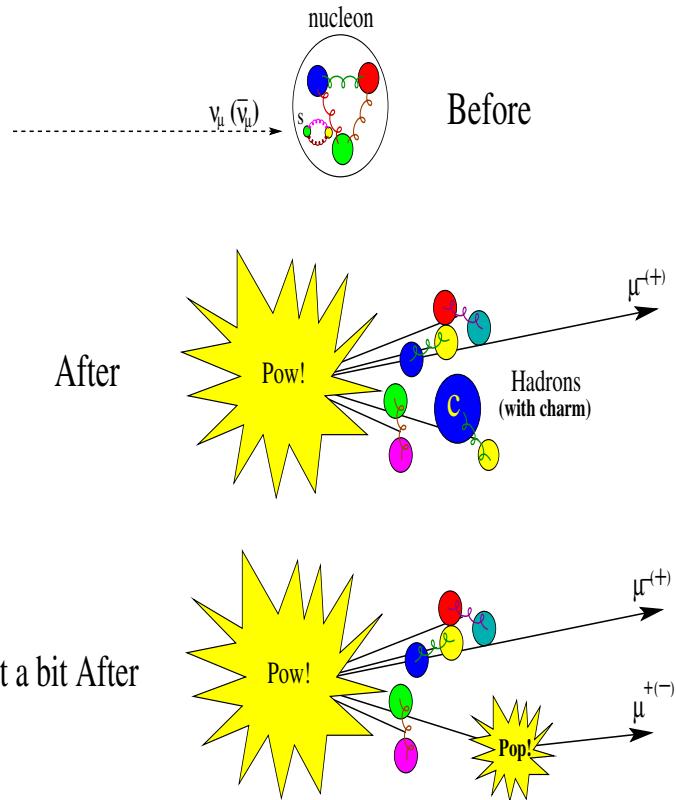


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Dimuons: $\nu + N \rightarrow X \mu^- \mu^+$

- Charged Current Dimuons
- **Uniquely sensitive to s , \bar{s} seas**
- Take advantage of NuTeV SS beam
- First complete NLO QCD analysis of this process, and:
 - with correctly evolved pdfs
 - satisfying QCD sum rules
 - using modern nuclear corrections

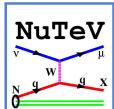


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The Experiment: NuTeV

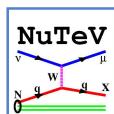
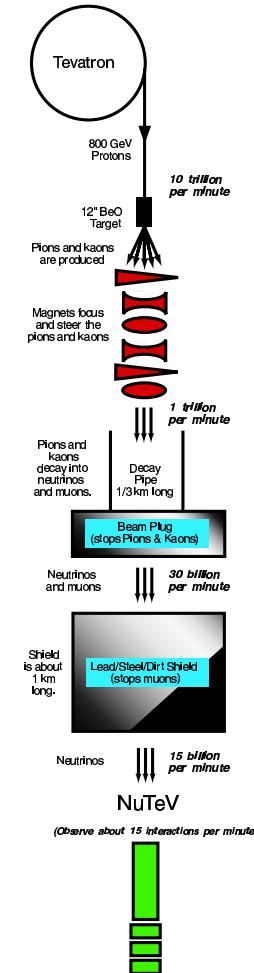
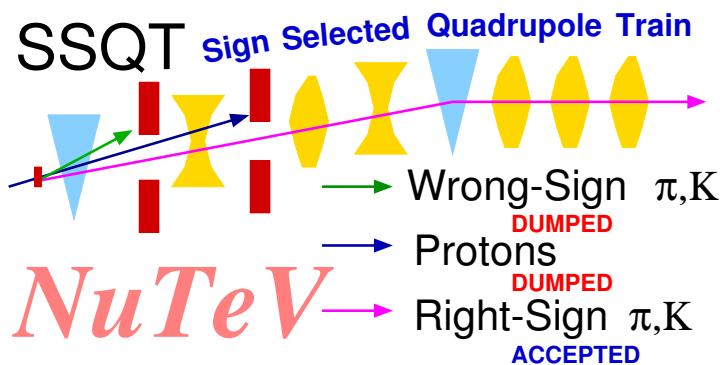
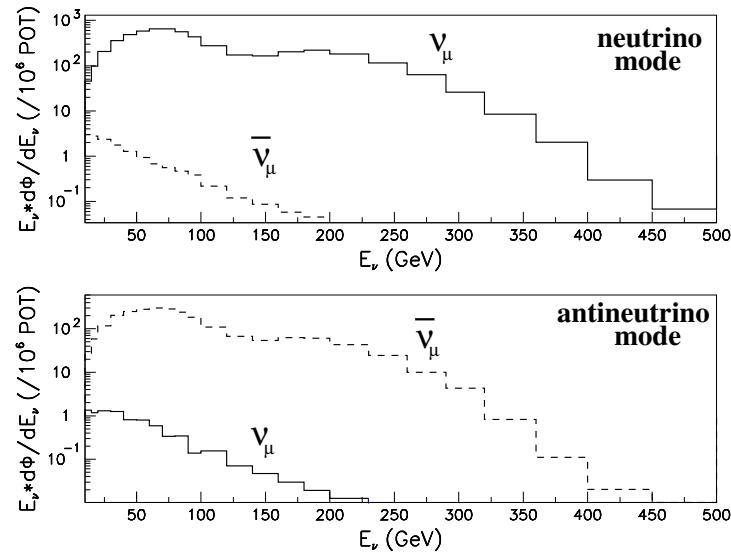
- ν -N DIS ($\langle E_\nu \rangle \sim 120\text{GeV}$)
- FNAL '96-'97 fixed target run
- 3.15×10^{18} protons on target
 - 886,004 ν , 255,045 $\bar{\nu}$ CC events
 - 5163 ν and 1380 $\bar{\nu}$ Dimuons
- Detector calibration beam throughout run
 - hadron, e , and muon beams
- High purity, selectable ν and $\bar{\nu}$ beams



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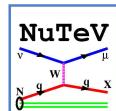
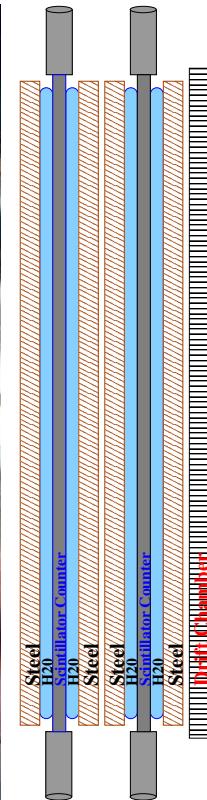
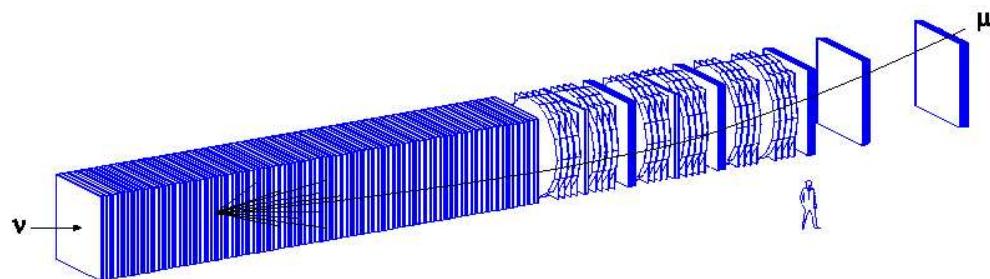
Sign Selected Beam: SSQT



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The NuTeV Detector

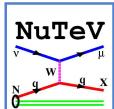
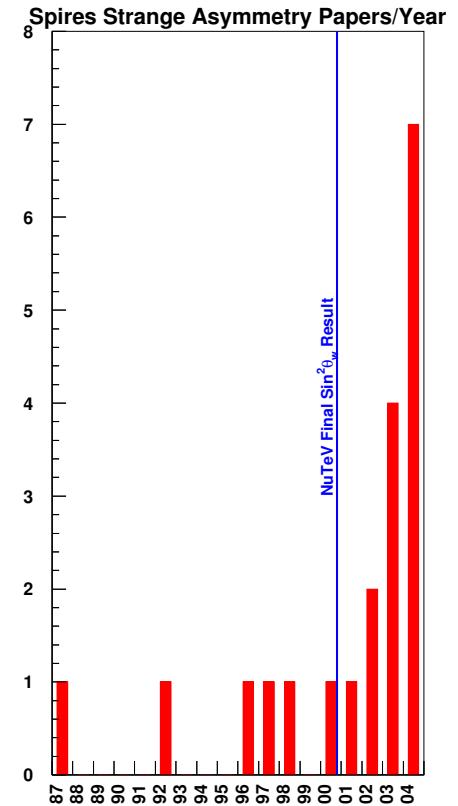


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$\sin^2 \theta_W$ and the Strange Asymmetry

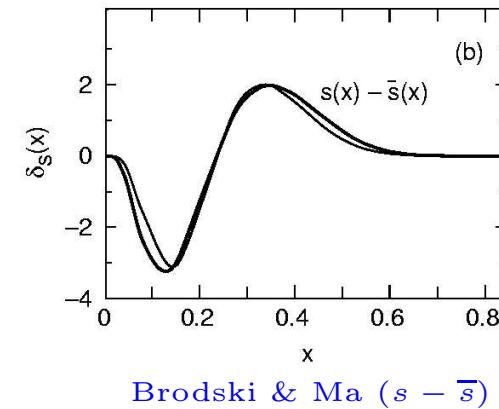
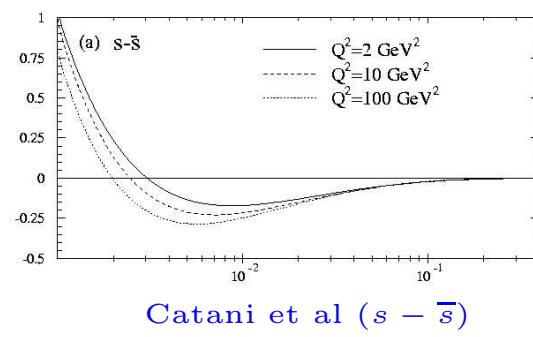
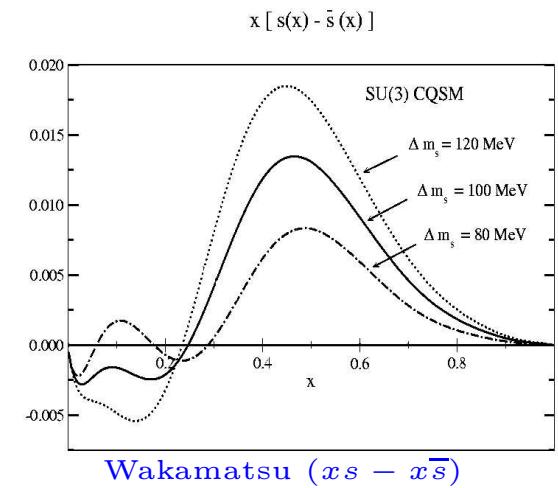
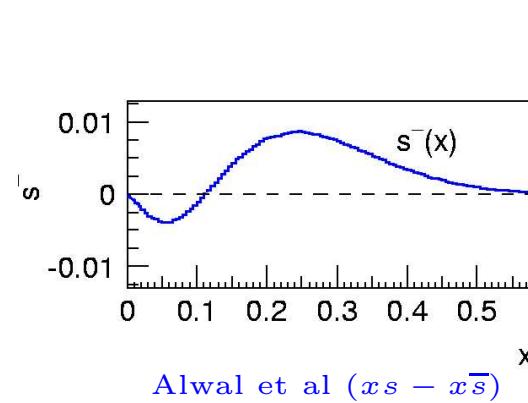
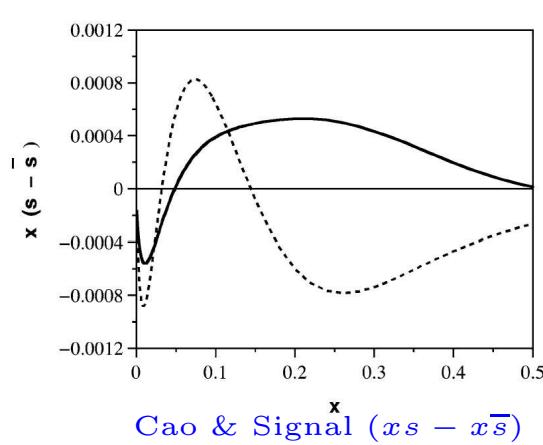
- NuTeV measured $R^- = \frac{\sigma_{NC}^\nu - \sigma_{\bar{NC}}^{\bar{\nu}}}{\sigma_{CC}^\nu - \sigma_{\bar{CC}}^{\bar{\nu}}}$
- From that $\sin^2 \theta_W$ was extracted
 - Insensitive to sea quark uncertainties
 - But assumed $s(x) = \bar{s}(x)$
- 0.22773 ± 0.00135 (stat) ± 0.00093 (syst)
(Zeller et al: PRL 88 (2002) 091802)
- 3σ above world average
- R^- correction from asymmetric strange sea is proportional to $S^- \equiv \int x[s(x) - \bar{s}(x)]dx$
- Led to much theoretical speculation \Rightarrow
- $S^- \sim 0.0068$ required to bring to world ave.



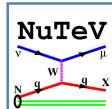
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A Pantheon of Asymmetry Predictions



NuTeV can directly measure this!

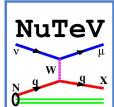
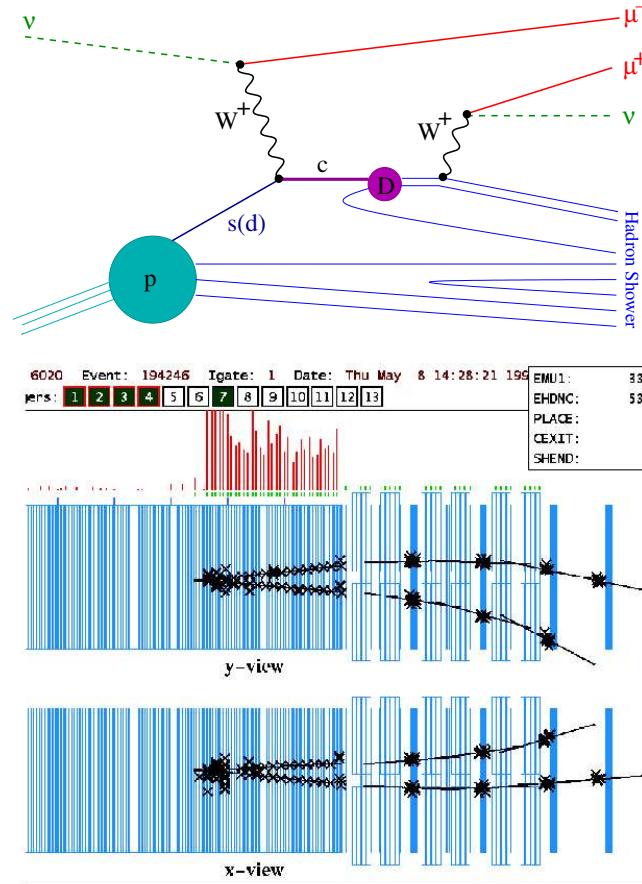


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Charm Production \Rightarrow Dimuons

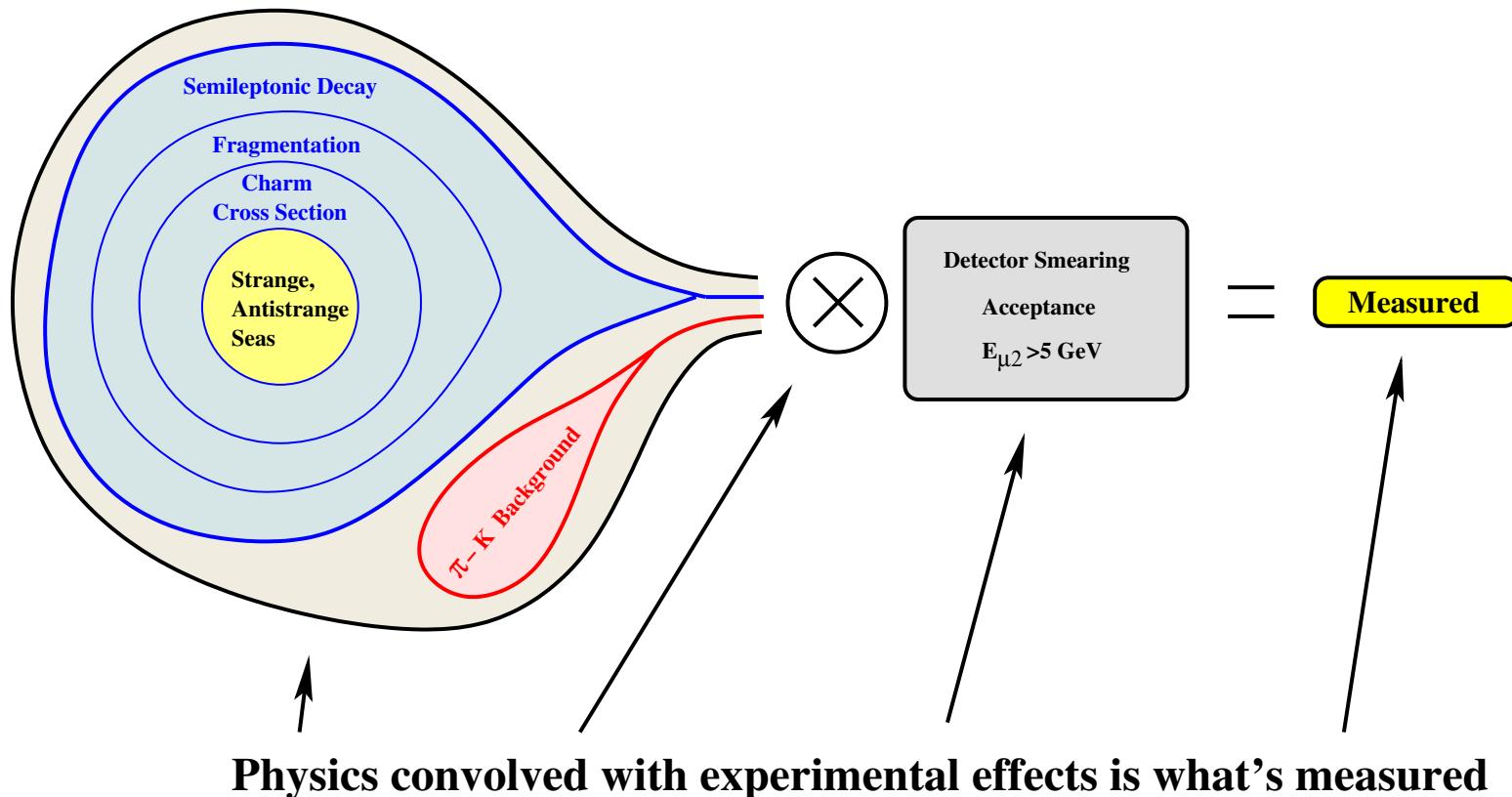
- CC νN makes charm
→ fragmentation
→ semileptonic decay to μ
- Very clear signature
- Direct look at strange sea
- With sign selected beam NuTeV can look at $s(x)$, $\bar{s}(x)$ independently
- Can also measure charm mass



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The Onion Representation of Dimuons



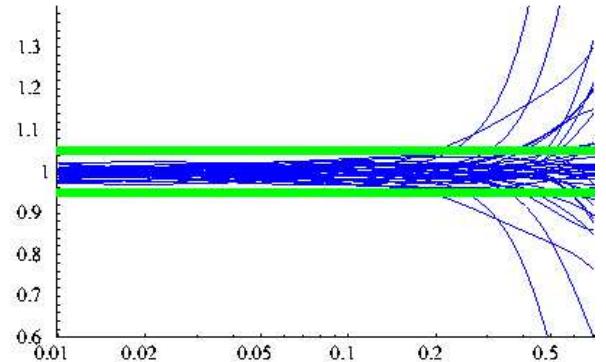
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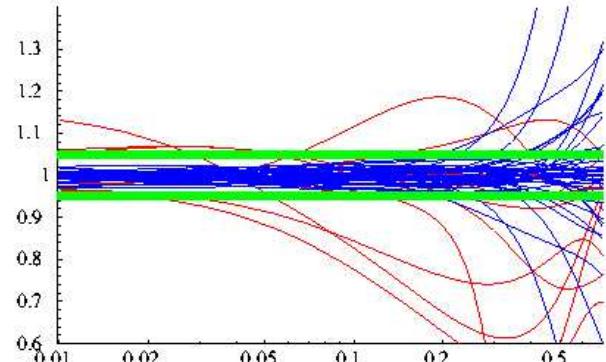
The Strange Uncertainty

- Not well constrained in global fits
(through structure function differences)
- Parameterizations (e.g. CTEQ, MRST...) typically assume $s = \bar{s} = 0.2(\bar{u} + \bar{d})$
- Uncert. in pdf sets represent $\bar{u} + \bar{d}$ error, not error on strange
- Freeing strange in CTEQ6 fit \implies
- **Dimuon data is needed!**
- (But must be in useful form for fits)

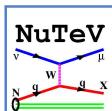
Standard CTEQ6 40 pdfs:



Freeing strange param:



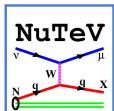
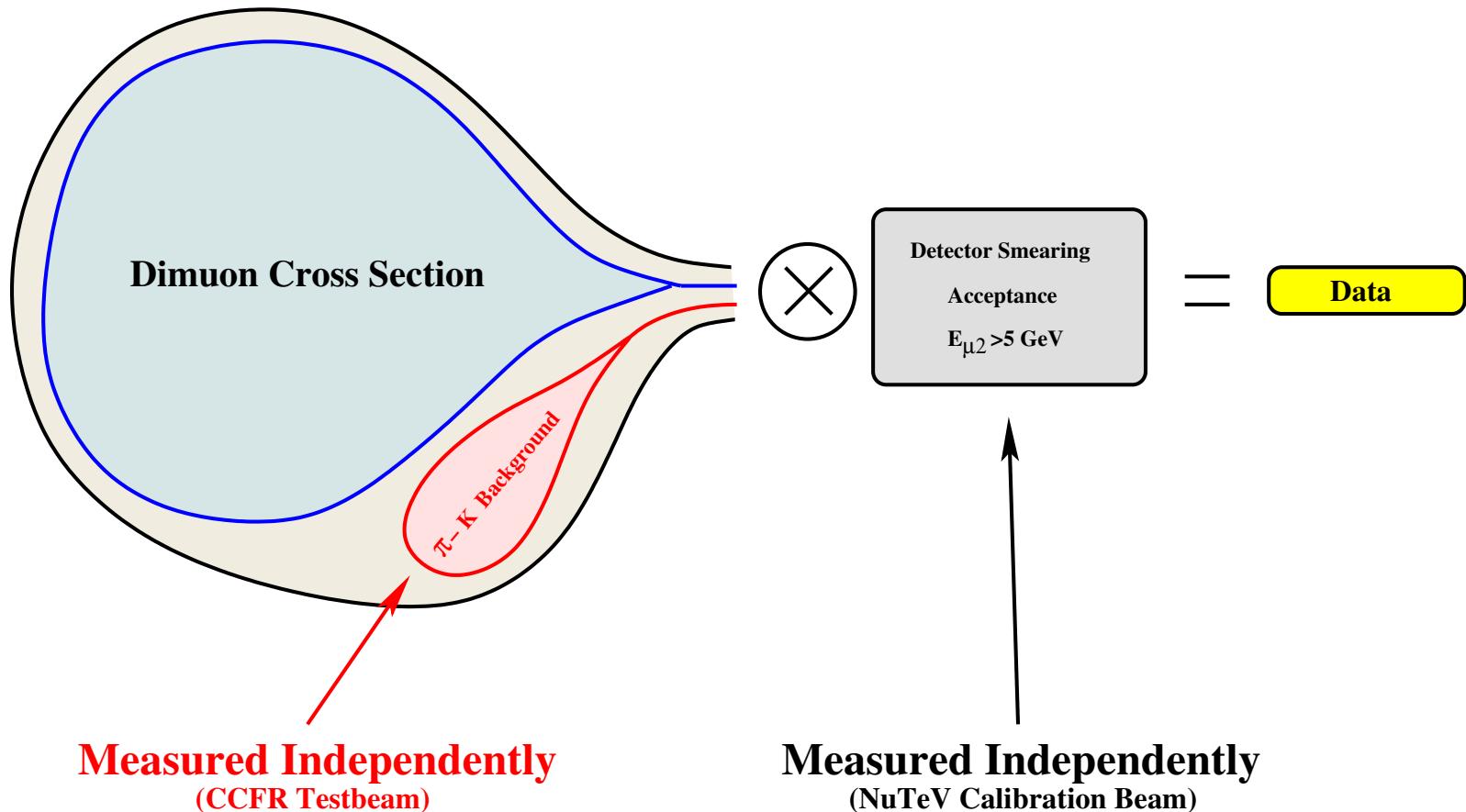
(F. Olness talk DIS 2005)



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The Dimuon Cross Section



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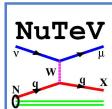
The Forward Dimuon Cross Section

- Measure Dimuon rather than charm cross section
- Eliminates model dependence from:
 - Semileptonic Decay
 - Fragmentation
 - Order in α_s of Cross Section
- Model dependence only from effects which cross “ \otimes ” boundary
- Minimized in high acceptance events ($E_{\mu-charm} > 5$ GeV)



Forward Dimuon Cross Section: Cross section of dimuon events in iron such that the charm decay muon has energy > 5 GeV.

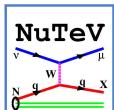
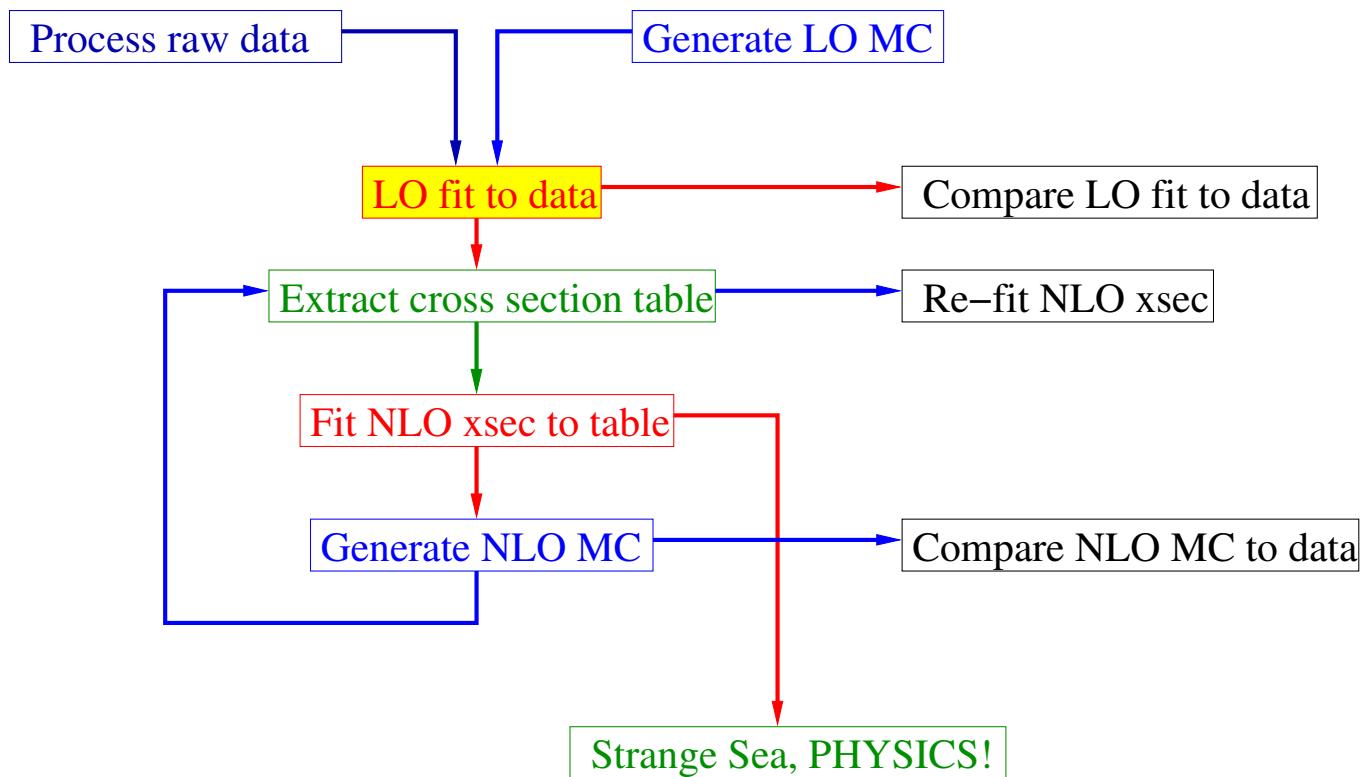
(Goncharov et al:PRD64 (2001) 112006)



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A flowchart of this analysis



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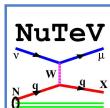
LO Fit Results

	m_c	ϵ	κ	$\bar{\kappa}$	α	$\bar{\alpha}$	B_c
Central Value	1.39	1.59	0.346	0.296	2.03	1.55	0.1214
Statistical Error	0.21	0.24	0.063	0.038	0.81	0.45	0.011
$\nu \pi\text{-K}$ (15%)	0.07	0.30	0.016	0.021	0.04	0.00	0.007
$\bar{\nu} \pi\text{-K}$ (21%)	0.00	0.08	0.001	0.014	0.00	0.25	0.001
Emuff scale (1%)	0.05	0.12	0.022	0.017	0.25	0.06	0.007
Emu2 rangeout	0.12	0.25	0.022	0.016	0.02	0.18	0.005
Had energy scale (0.5%)	0.01	0.07	0.009	0.004	0.06	0.02	0.001
R_L (20%)	0.07	0.02	0.008	0.005	0.42	0.26	0.002
MC statistics	0.02	0.01	0.006	0.004	0.03	0.02	0.001
Flux norm	0.00	0.00	0.000	0.002	0.00	0.01	0.000
Total Systematics	0.17	0.43	0.037	0.035	0.49	0.41	0.011

- $\chi^2 = 111/106$ DoF
- Internal pdfs based on NuTeV structure function measurements
- Collins-Spiller fragmentation

$$s(x) = \kappa(1-x)^\alpha \left(\frac{\bar{u}(x)+\bar{d}(x)}{2} \right)$$

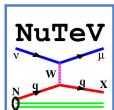
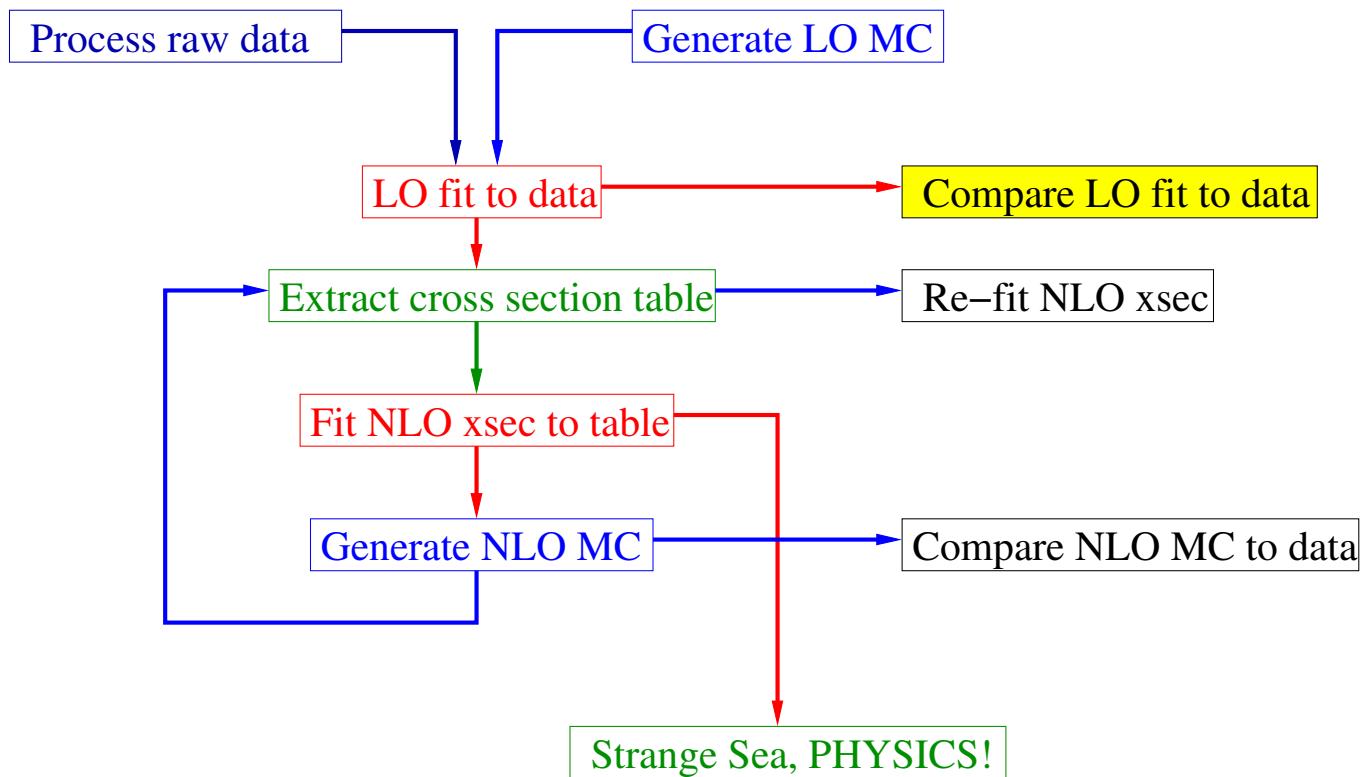
$$\bar{s}(x) = \bar{\kappa}(1-x)^{\bar{\alpha}} \left(\frac{\bar{u}(x)+\bar{d}(x)}{2} \right)$$



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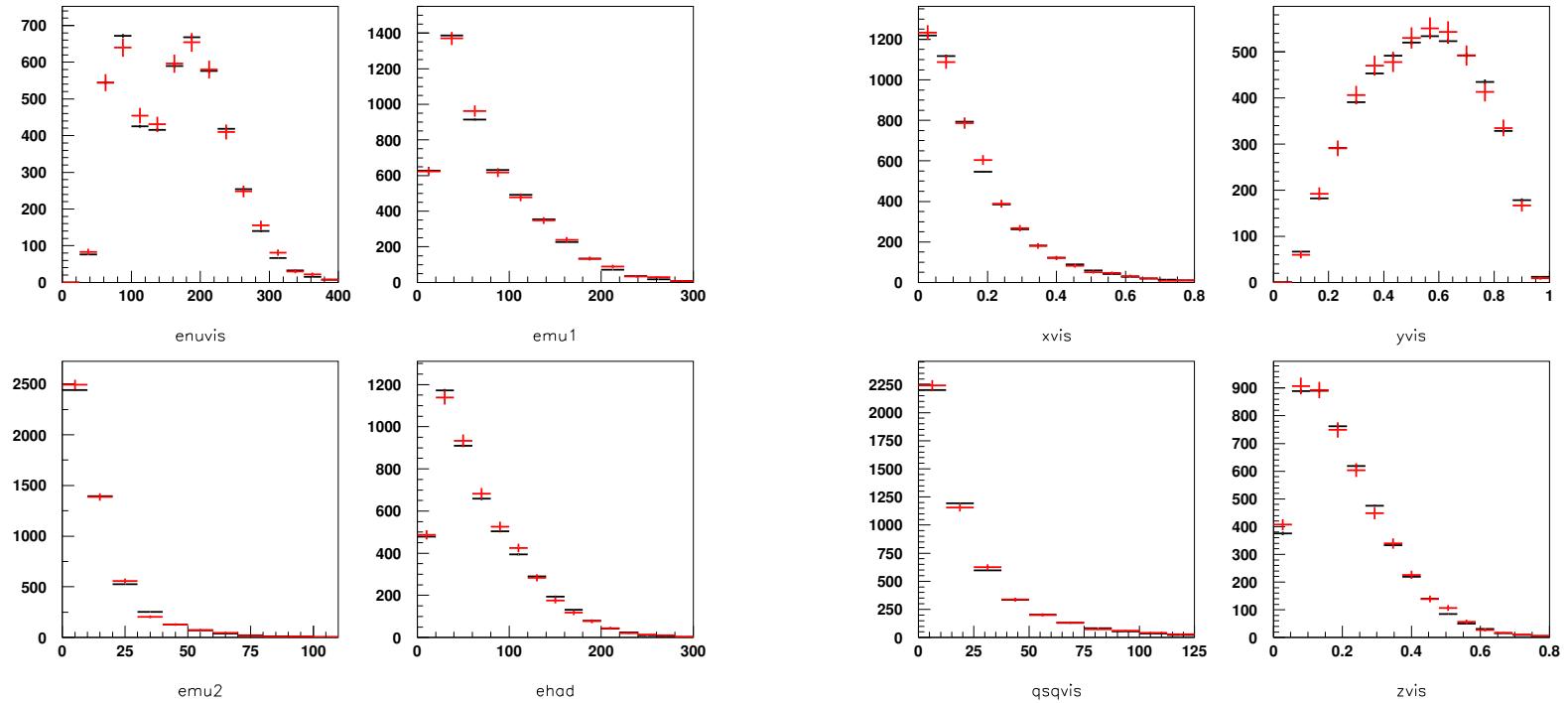
Compare LO Fit to Data



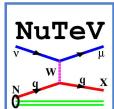
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Good LO Data/MC Agreement: Neutrinos



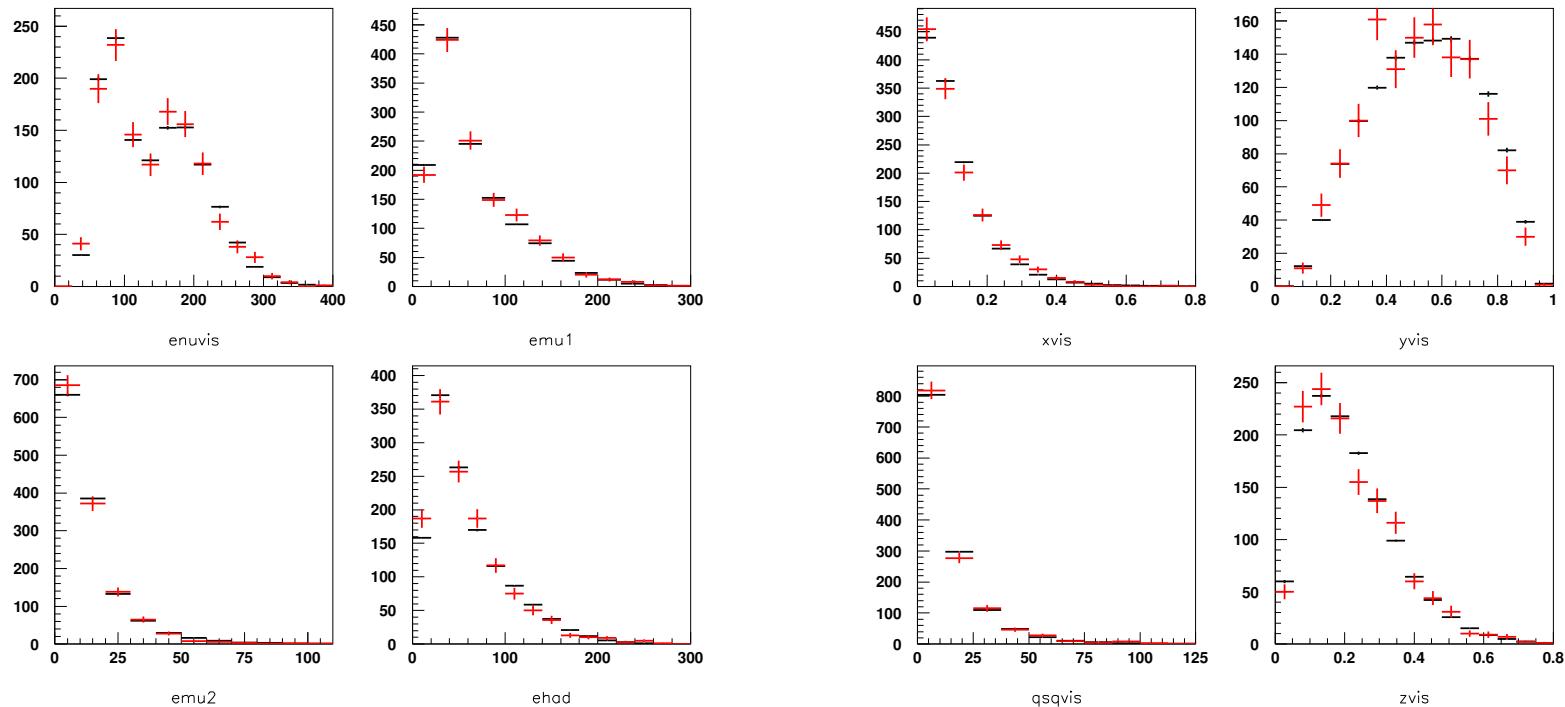
- Red points are data, black is MC



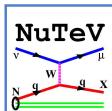
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Good LO Data/MC Agreement: Antineutrinos



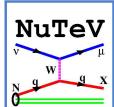
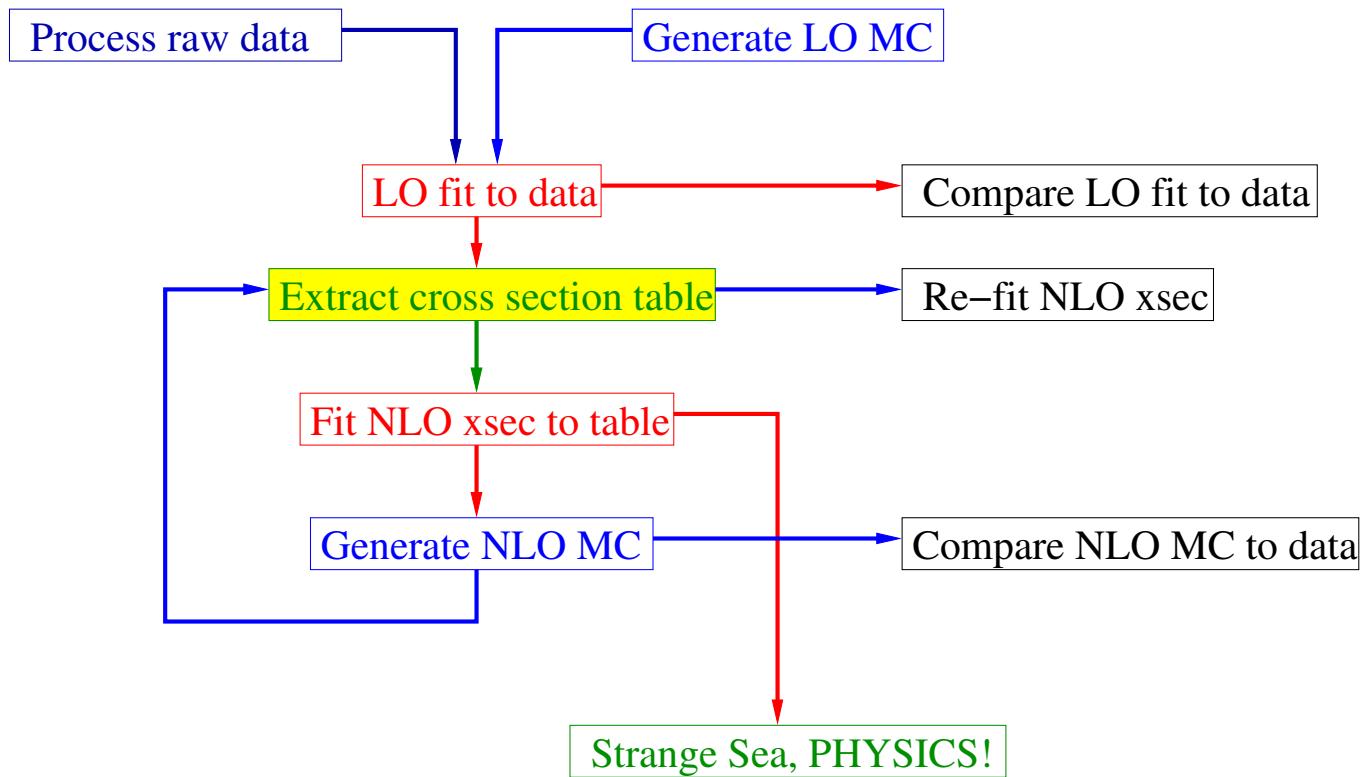
- Red points are data, black is MC



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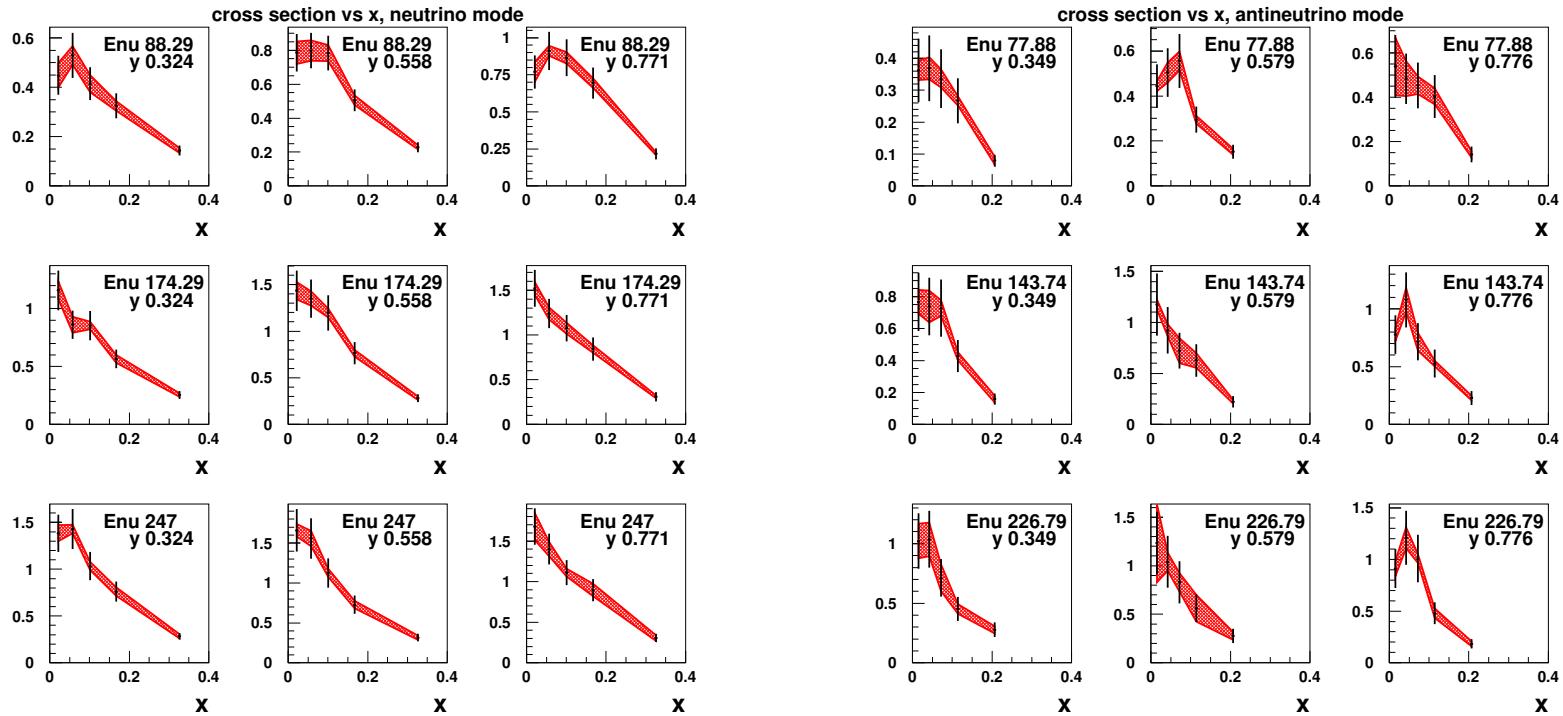
Extract Cross Section Table



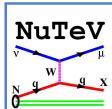
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Forward Dimuon Cross Section Table



- Plotting xsec vs x, normalized so $\frac{G_F^2 M_E}{\pi} = 1$



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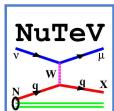
With the LO model having served its purpose



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We now move to NLO:

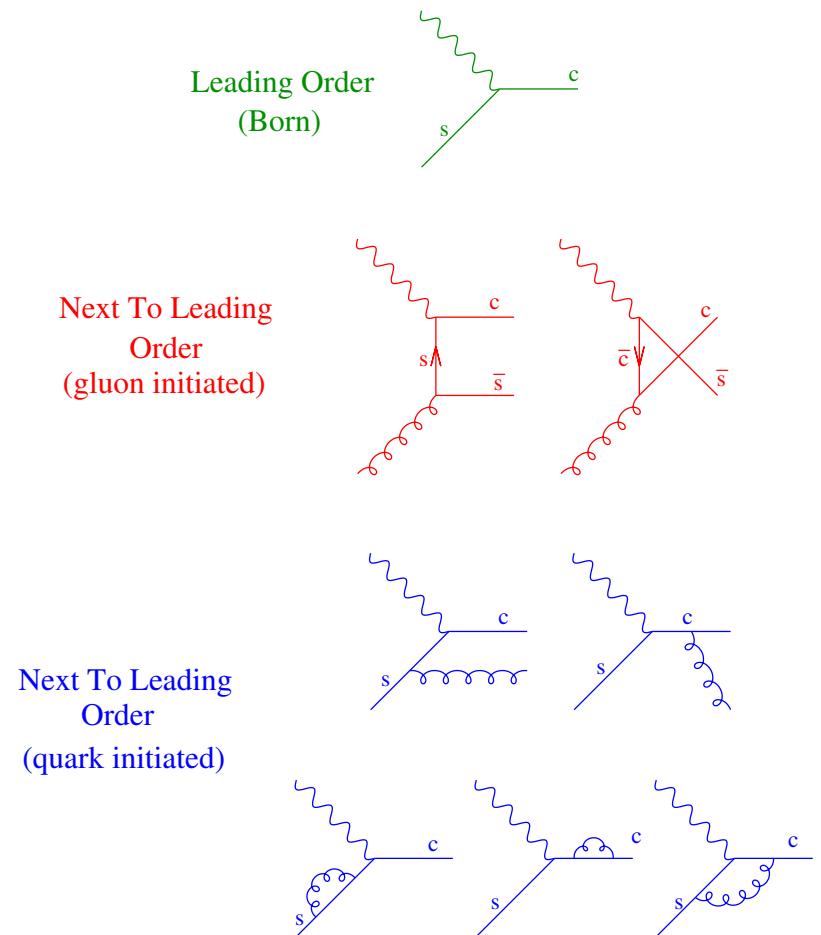
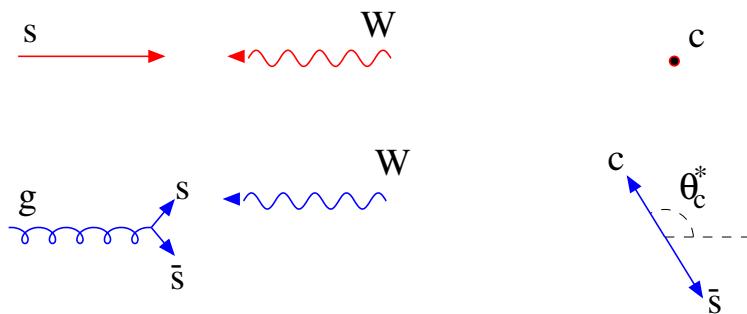


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Why NLO?

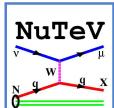
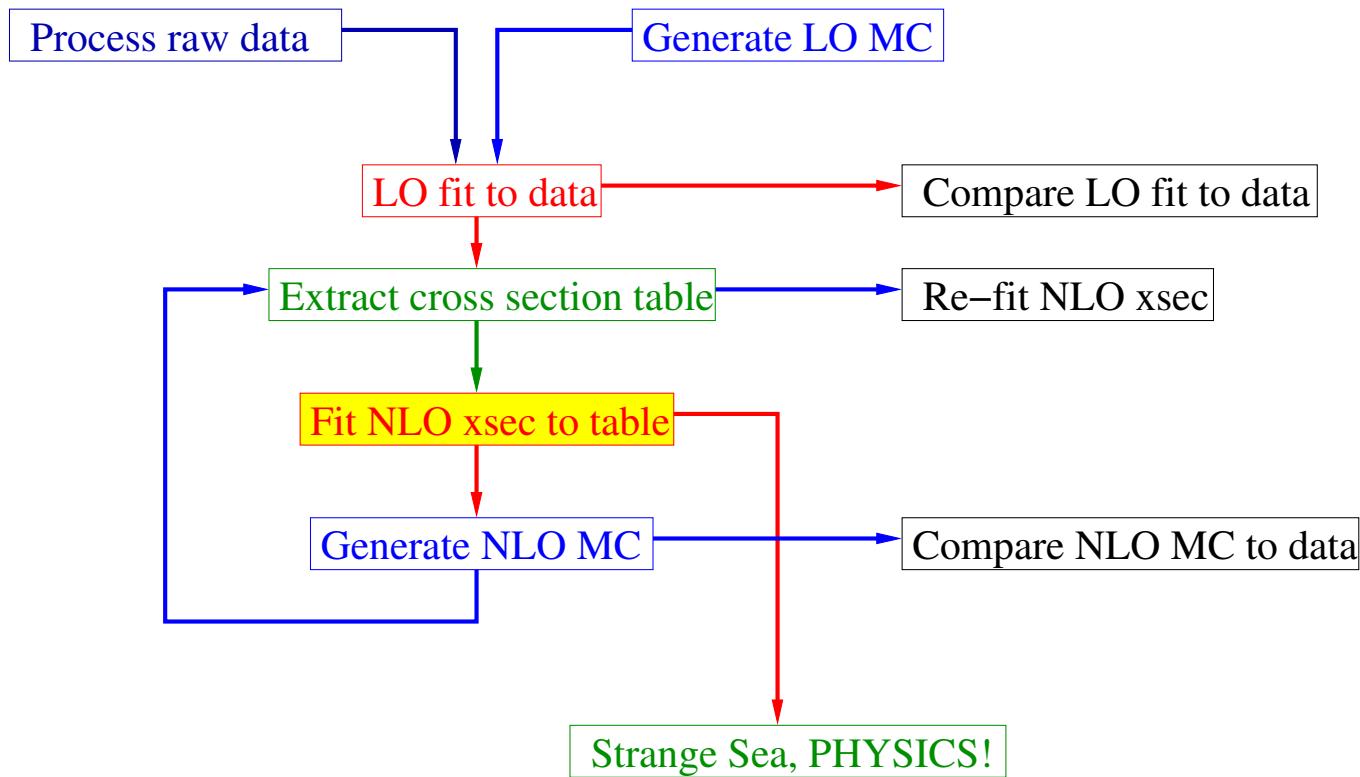
- 1st order in QCD
- NLO of global interest
- Substantial gluon pdf
- But fragmentation requires convolution integral
- Dimuon acceptance depends on z , charm p_\perp



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Fit NLO Xsec to Table



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Elements in Dimuon Cross Section Table Fit

$$\frac{d\sigma_{charm}(E_\nu, x, y; m_c, s, \bar{s})}{dxdy} \otimes \mathcal{N}(A, x, Q^2) \cdot B_c \cdot \mathcal{A}_{\mu 2}(E_\nu, x, y; \epsilon, m_c) = \boxed{\text{fit}} \Rightarrow \frac{d\sigma_{2\mu}(E_\nu, x, y)}{dxdy}$$

$$\frac{d\sigma_{2\mu}(E_\nu, x, y)}{dxdy}$$

Measured NuTeV dimuon cross section

$$\frac{d\sigma_{charm}(E_\nu, x, y; m_c, s, \bar{s})}{dxdy}$$

Calculated inclusive charm cross section.
depends on m_c , strange and antistrange seas.

$$\mathcal{N}(A, x, Q^2)$$

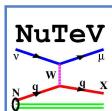
Nuclear corrections (iron target, proton pdfs)
dependent on nucleus A , x , and Q^2 , is convolved with pdf

$$B_c$$

Semileptonic branching ratio.

$$\mathcal{A}_{\mu 2}(E_\nu, x, y; \epsilon, m_c)$$

Acceptance function due to the 5 GeV cut on the muon
from semileptonic charm decay $\left(\frac{\mathcal{N}(E_{\mu 2 g} > 5 \text{GeV})}{\mathcal{N}(\text{all})} \right)$.

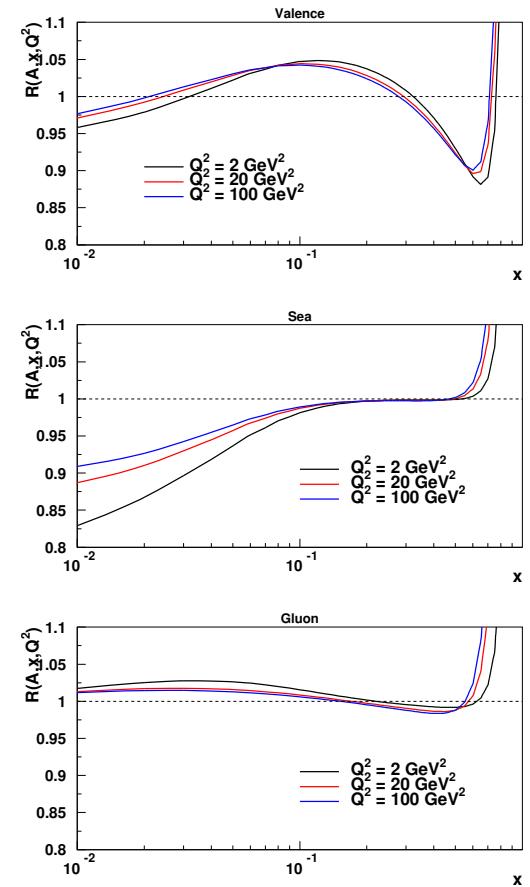


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Nuclear Corrections: $\mathcal{N}(A, x, Q^2)$

- Proton based global fit pdf's require nuclear corrections (iron target)
- \mathcal{N} depends on nucleus type, x , and Q^2
 - And whether valence, sea quarks or gluons involved
- Past analyses have used simple Q^2 independent parameterization
- First time \mathcal{N} from global fits have been used
- de Florian et al, NLO corrections \Rightarrow

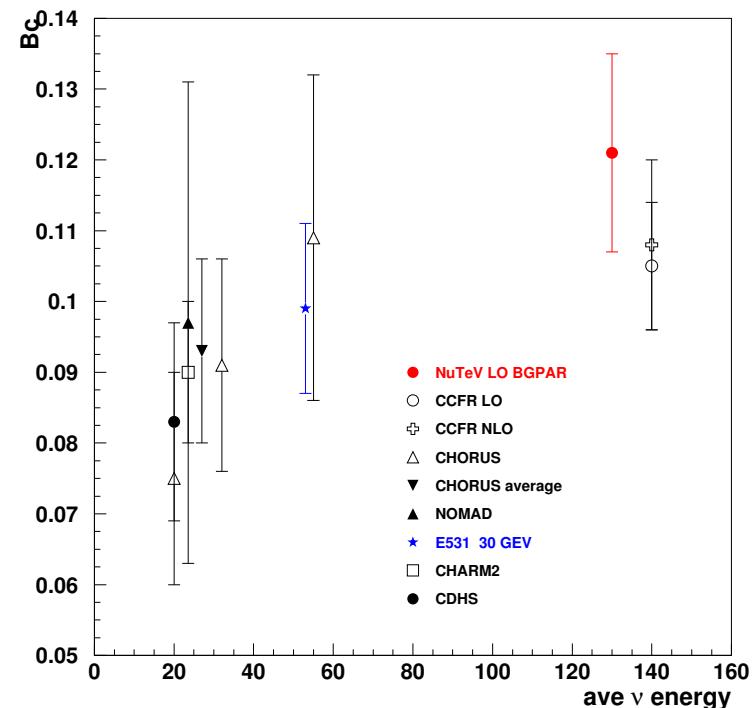


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Semi-muonic Branching Ratio: B_c

- B_c is an average semi- μ branching ratio over all charm states
- Fitting to cross section table requires taking from external measurements
- 2004 PDG value of 0.099 ± 0.012 used
- B_c uncertainty \Rightarrow half of uncertainty in strange asymmetry measurement



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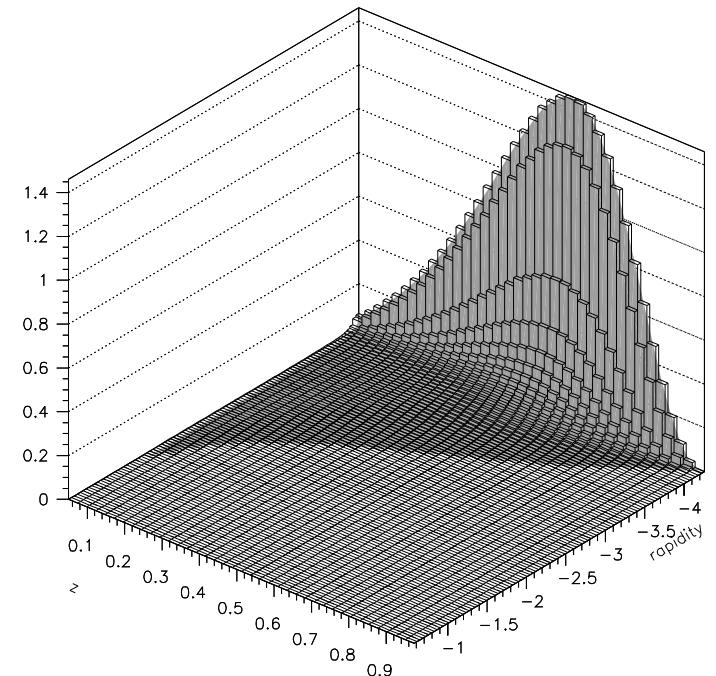


$E_{\mu-charm} > 5$ GeV Acceptance $\mathcal{A}_{\mu 2}$ -DISCO!

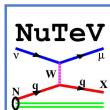
- Fitting table requires $E_{\mu 2} > 5$ GeV acceptance correction
- 2μ acceptance depends on fragmentation
- Also depends on charm p_\perp at NLO
- \Rightarrow need cross section differential in both
- I.e. need:

$$\frac{d\sigma_{charm}}{d\xi \ dy \ dz \ d\eta_c}$$

where $\eta_c = \frac{1}{2} \log \frac{E_c + p_{c\parallel}}{E_c - p_{c\parallel}}$
 (i.e. a true rapidity, not pseudorapidity)



(Kretzer, Olness & Mason: Phys.Rev.D65:074010,2002)

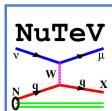
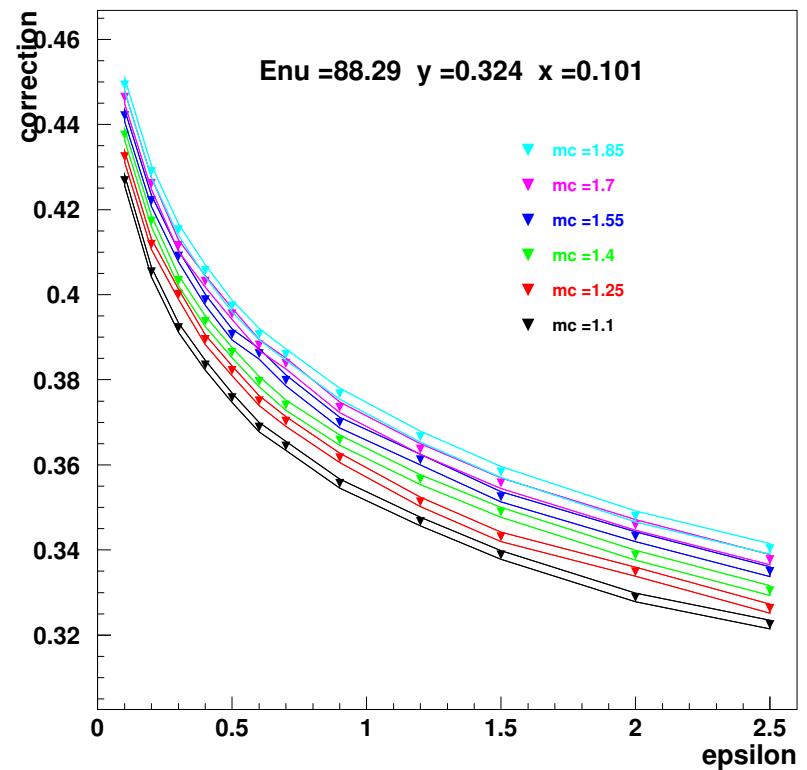


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Acceptance Tables

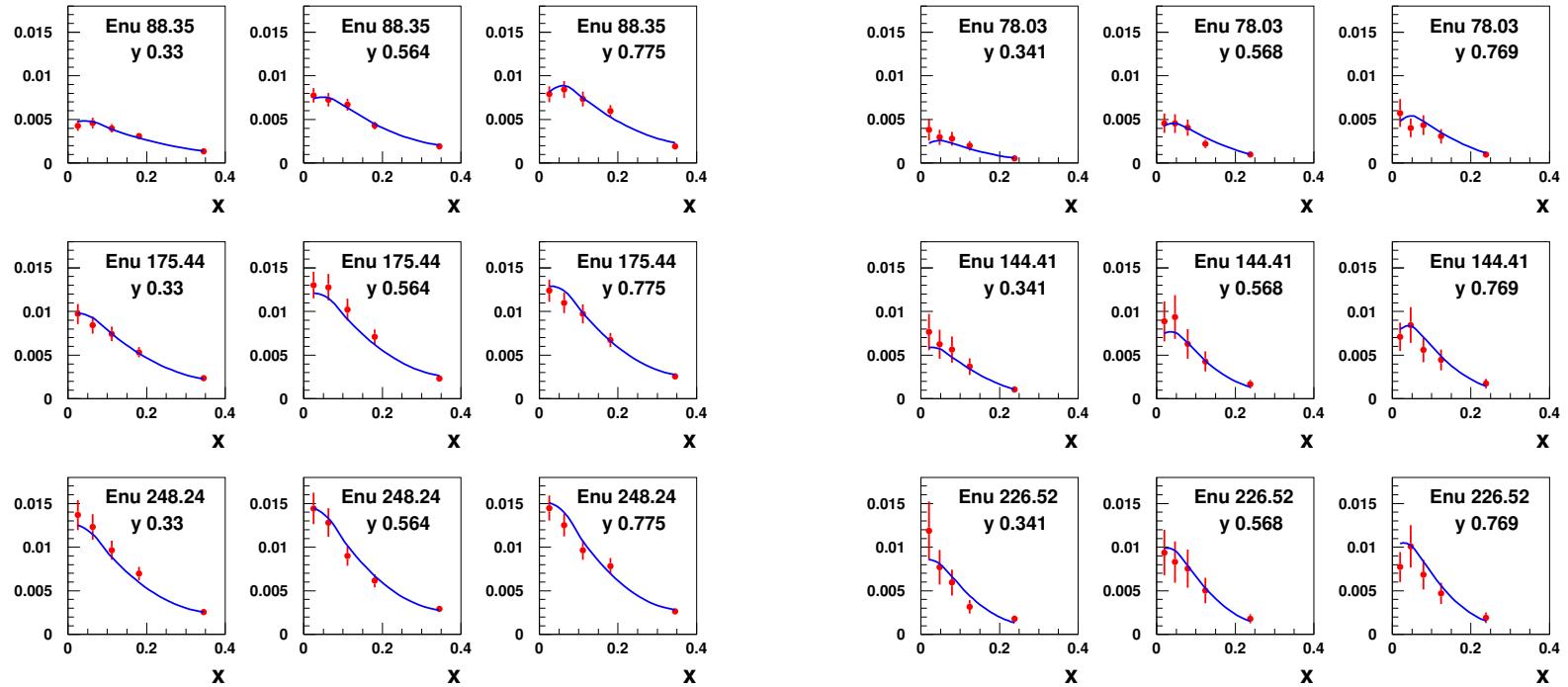
- Ratio of dimuons which pass $E_{\mu-charm} > 5$ GeV cut
- Acceptances calculated for each of 90 table points (1 shown) \Rightarrow
- In grid of 12 ϵ , 6 m_c points
 - m_c dependence is NLO effect from rapidity
- In each table bin, 20 $z \times 40 \eta_c$ bins
- Decay 20,000 dimuons in each
- Approx 1×10^{11} MC events total!



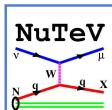
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NLO fit to table



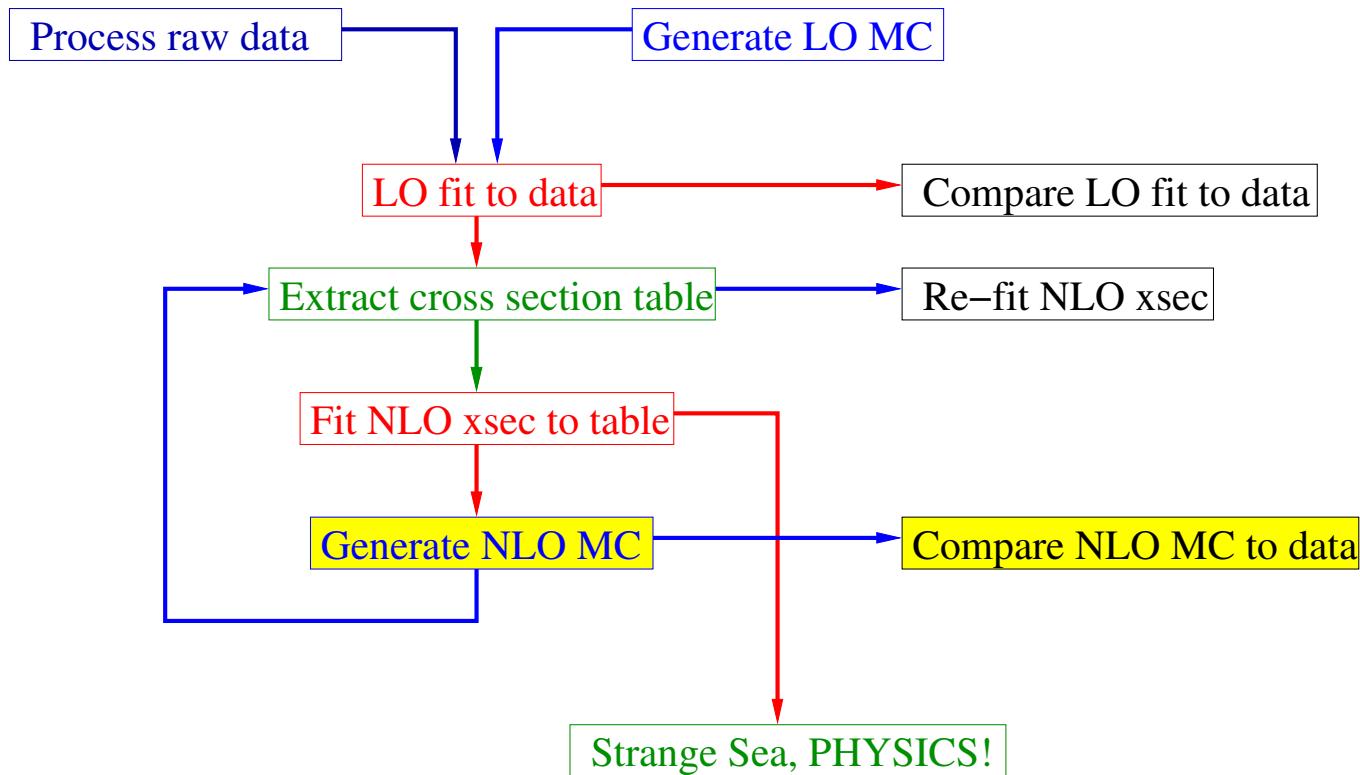
- Plotting xsec vs x , normalized so $\frac{G_F^2 M_E}{\pi} = 1$



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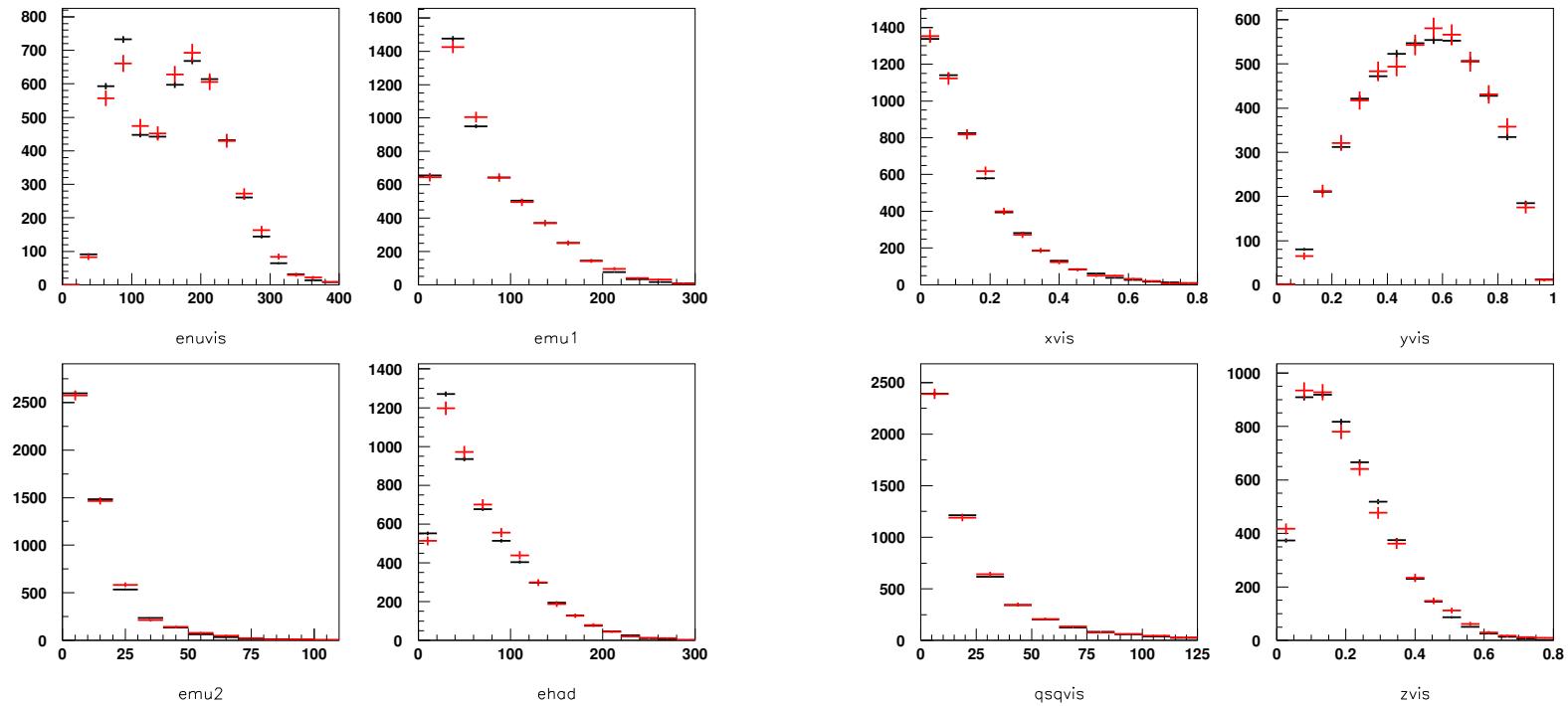
Generate NLO MC and Compare it to Data



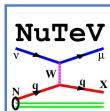
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CHECK: Good NLO Data/MC Agreement: Neutrinos



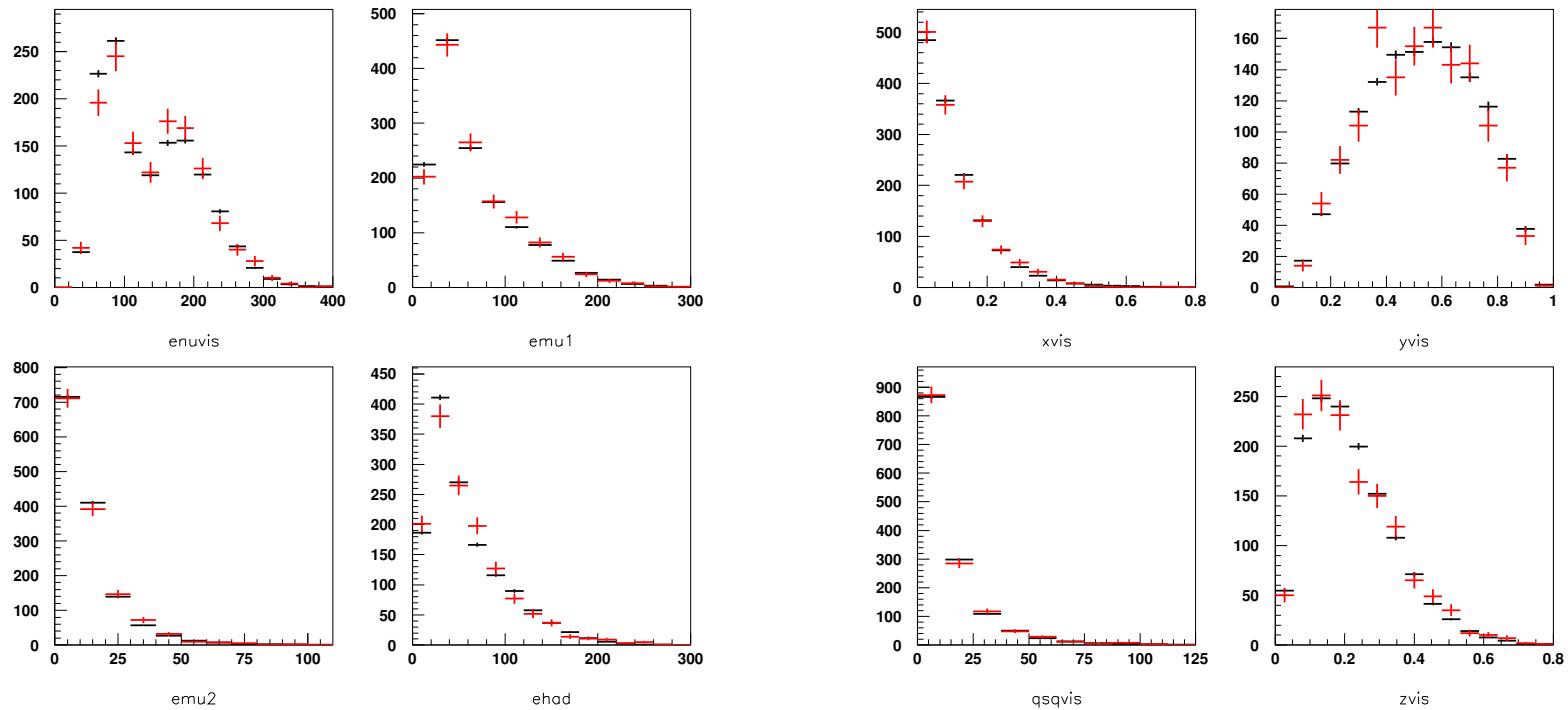
- Red points are data, black is MC



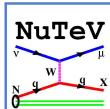
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CHECK: Good NLO Data/MC Agreement: Antineutrinos



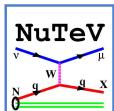
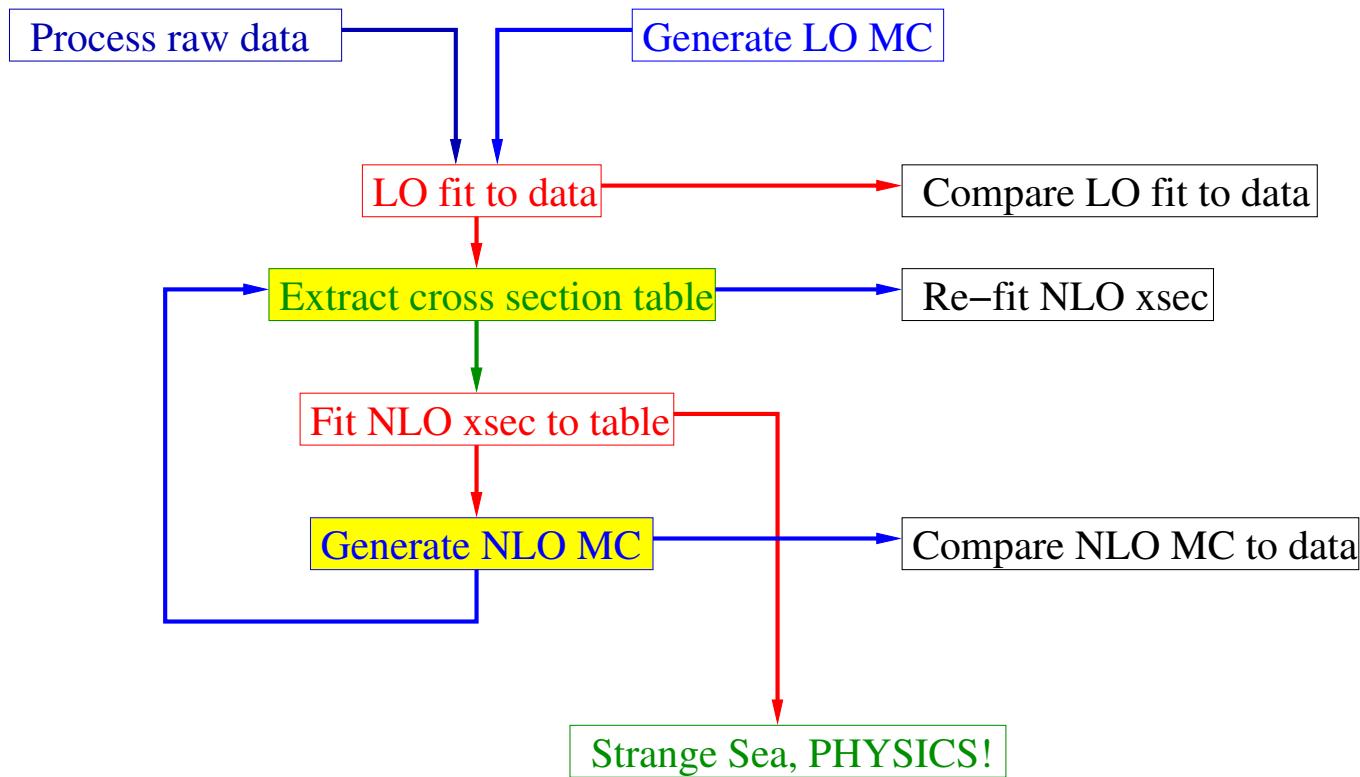
- Red points are data, black is MC



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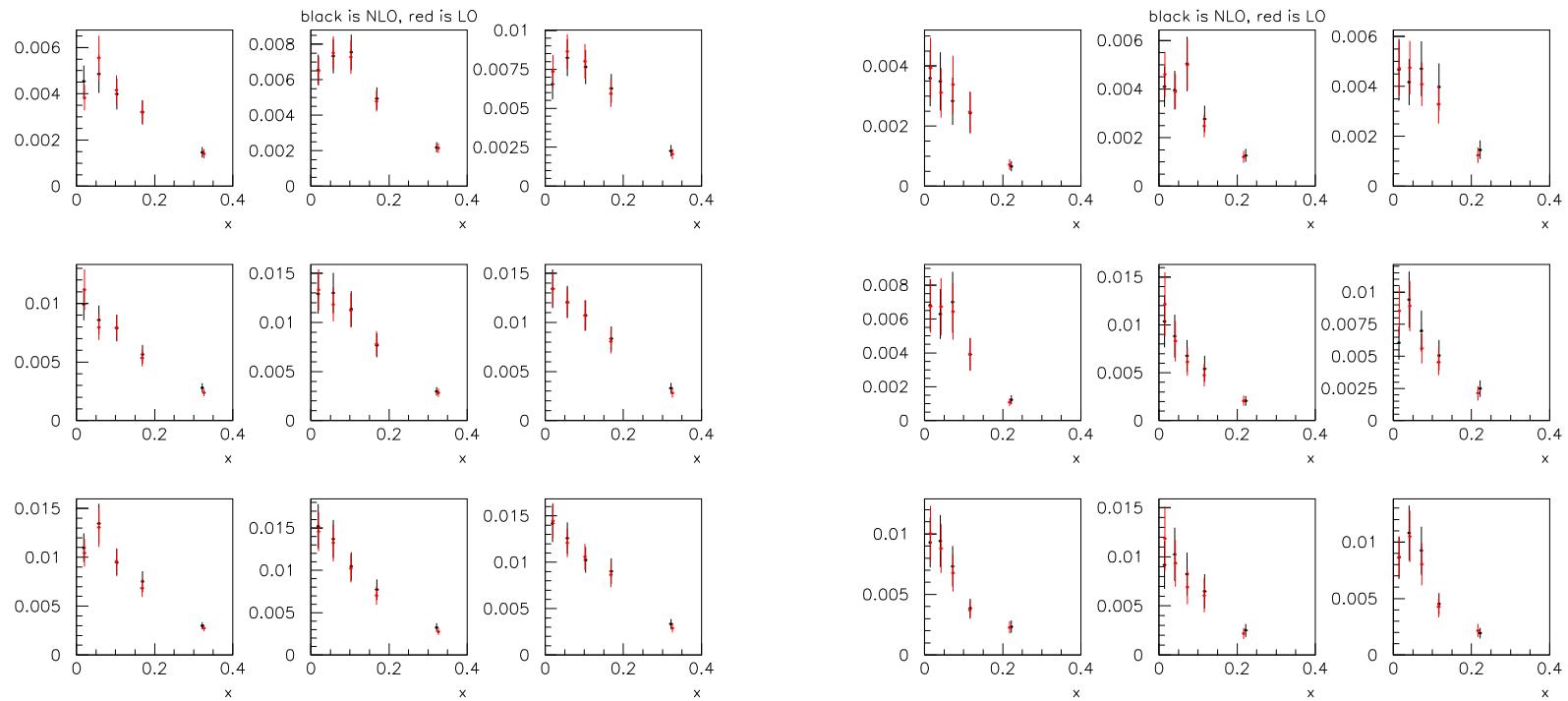
Re-Extract Cross Section Table at NLO



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CHECK: NLO re-extracted table vs original



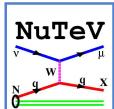
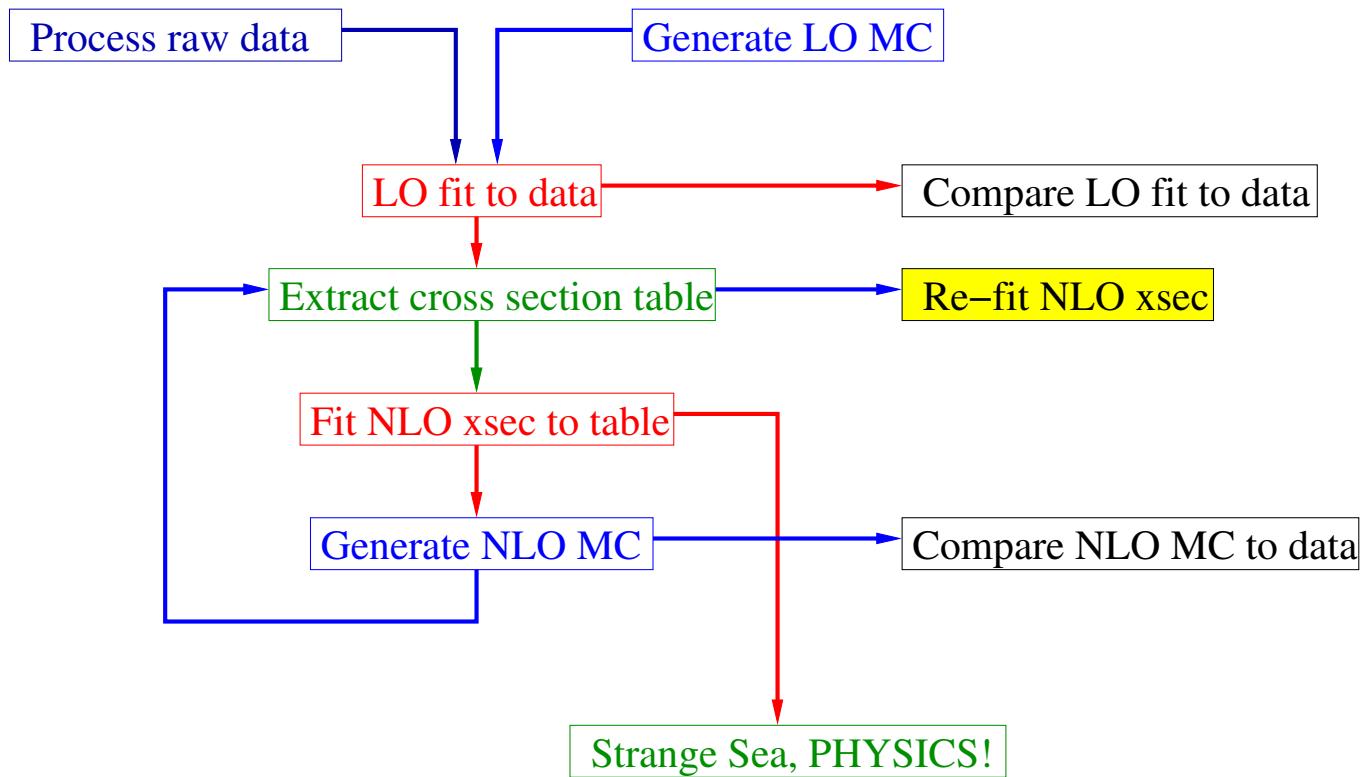
- Plotting xsec vs x , normalized so $\frac{G_F^2 M_E}{\pi} = 1$



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Re-fit NLO xsec

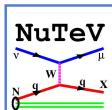
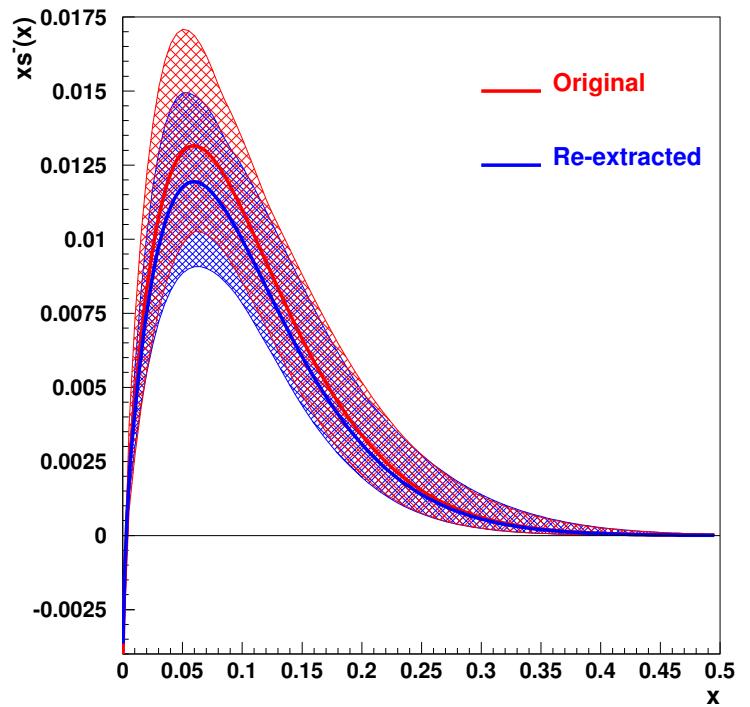


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CHECK: Comparing Strange Asymmetries

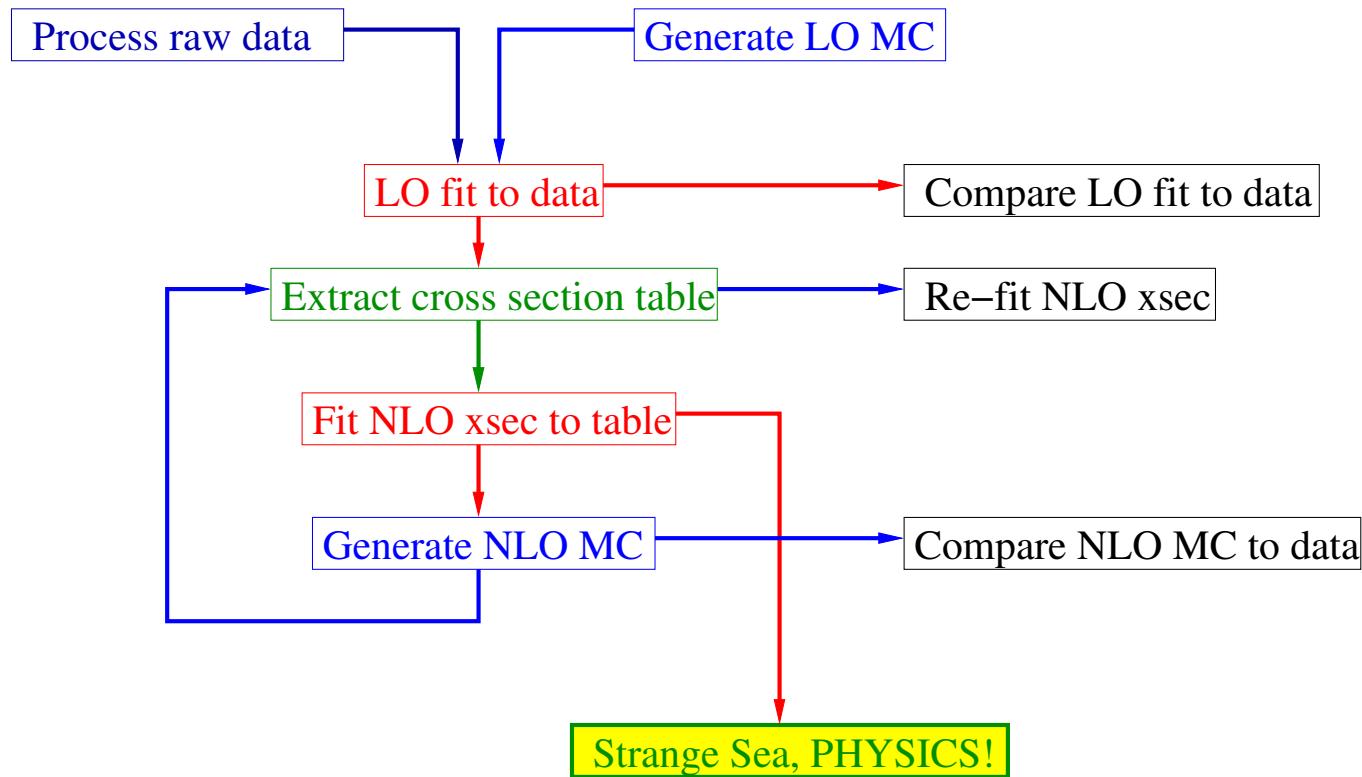
- Just comparing tables doesn't tell whole story
- Need to re-fit and see if we get same answer
- The two asymmetries agree well
- Only statistical errors shown



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Physics!



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Physics!

- Performed several fits, taking charm mass, nonstrange pdfs, branching ratio from external measurements:
 1. Treating strange/antistrange seas as modification of pre-evolved pdfs
 2. Defining s , \bar{s} pdfs at Q_0 , evolving properly
 3. Using CTEQ parameterization, evolving properly, satisfying sum rules
 4. Allowing m_c to float
- Also studied dependence of strange asymmetry on shape



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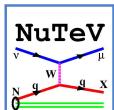
Traditional fit first...

$$s(x, Q^2) = \kappa(1-x)^\alpha \left[\frac{\bar{u}(x, Q^2) + \bar{d}(x, Q^2)}{2} \right]$$

$$\bar{s}(x, Q^2) = \bar{\kappa}(1-x)^{\bar{\alpha}} \left[\frac{\bar{u}(x, Q^2) + \bar{d}(x, Q^2)}{2} \right]$$

- $S^- = 0.0023 \pm 0.0006$ (stat)
 $(S^- \equiv \int x [s(x) - \bar{s}(x)] dx)$
- But do we get this answer because of the approximate QCD evolution?

Parameter	Value
m_c	1.20 GeV (fixed)
ϵ	0.60 (fixed)
κ	0.596 ± 0.028
$\bar{\kappa}$	0.521 ± 0.026
α	1.34 ± 0.49
$\bar{\alpha}$	1.54 ± 0.46
B_c	0.099 (fixed)



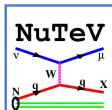
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To evolve properly...

$$\mu^2 \frac{d}{d\mu^2} \phi_{i,h}(x, \mu^2) = \sum_{j=q, \bar{q}, G} \int_x^1 \frac{d\xi}{\xi} P_{ij} \left(\frac{x}{\xi}, \alpha_s(\mu^2) \right) \phi_{j,h}(\xi, \mu^2)$$

- pdf must be solution of DGLAP equation (above)
- Define at an initial scale ($\mu_0 = Q_0$) then numerically solve to find pdf $\phi_{j,h}(\xi, \mu^2)$, at arbitrary scale, μ .
- Some freedom in pdf definitions is required ($s \neq \bar{s}$)
- Use modified version of EVLCTEQ evolution code which allows $s \neq \bar{s}$ (thanks to Wu-Ki Tung)
- Use LHApdf v1.2 package as a wrapper
- CTEQ6M pdfs, defining s, \bar{s} at $Q_0 = 1.3$ GeV

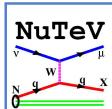


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Redo $\kappa - \alpha$ fit, evolving properly:

Description	κ	$\bar{\kappa}$	α	$\bar{\alpha}$	S^-
Central value	0.415	0.332	0.87	1.09	0.00195
Statistical error	0.031	0.030	0.68	0.71	0.00055
$\nu \pi\text{-K}$ (15%)	0.012	0.009	0.38	0.08	0.00041
$\bar{\nu} \pi\text{-K}$ (21%)	0.006	0.018	0.05	0.14	0.00031
Emuff scale (1%)	0.007	0.016	0.19	0.01	0.00002
Had energy scale (0.5%)	0.008	0.009	0.15	0.04	0.00010
R_L (20%)	0.011	0.018	0.06	0.02	0.00005
MC statistics	0.014	0.021	0.16	0.06	0.00000
Emu2 rangeout	0.013	0.021	0.31	0.06	0.00012
Flux norm	0.002	0.006	0.07	0.00	0.00000
Total Table Systematics	0.028	0.044	0.58	0.18	0.00054
Charm mass	0.015	0.011	0.07	0.14	0.00006
Fragmentation ϵ	0.009	0.009	0.25	0.06	0.00023
B_c	0.053	0.055	1.32	0.19	0.00125
Total External Measurement	0.056	0.057	1.35	0.24	0.00127
Total Systematics	0.063	0.072	1.47	0.30	0.00138

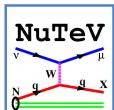
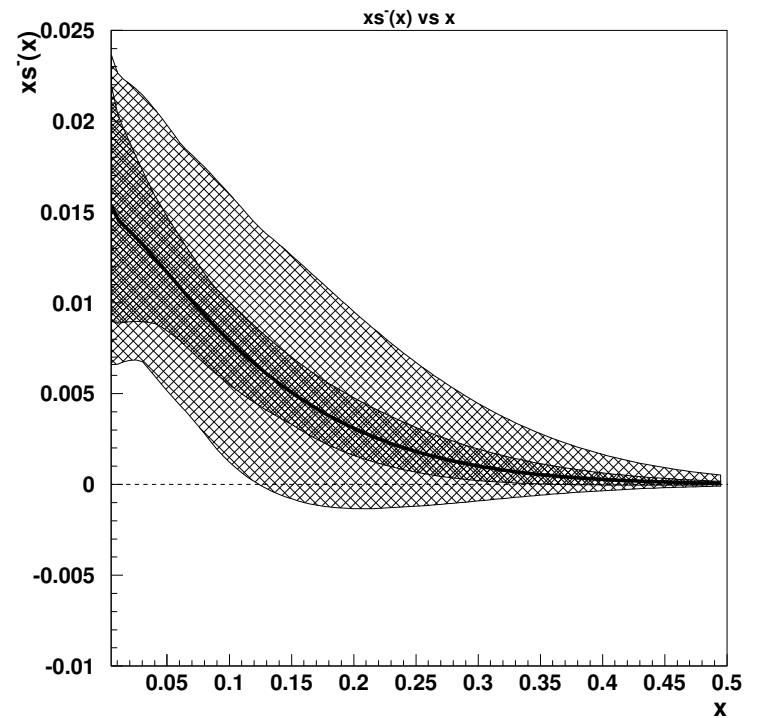


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$$\kappa - \alpha \ xs^-(x) \text{ vs } x$$

- $\chi^2 = 36.9$ out of 39.8 DoF
- $xs^-(x)$ vs x, inner band stat. error, outer band total \Rightarrow
- Asymmetry agrees well with approximate evolution fit
- But $\int_0^1 [s(x) - \bar{s}(x)]dx$ isn't zero.
- Technically should also satisfy sum rules.



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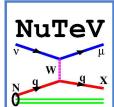


Further Satisfying QCD requirements

- Stepped up collaboration with phenomenologists
(Amundson, Kretzer, Olness, Soper, Tung)
- Trying a “CTEQ inspired” parameterization ([hep-ph/0312323](#))

$$\begin{aligned}
 s^+(x, Q_0) &= \kappa^+ (1-x)^{\alpha^+} x^{\gamma^+} \left[\bar{u}(x, Q_0) + \bar{d}(x, Q_0) \right] \\
 s^-(x, Q_0) &= s^+(x) \tanh \left[\kappa^- (1-x)^{\alpha^-} x^{\gamma^-} \left(1 - \frac{x}{x_0} \right) \right] \\
 s &= \frac{s^+ + s^-}{2} \quad \bar{s} = \frac{s^+ - s^-}{2}
 \end{aligned}$$

- Flavor sum rule satisfied by x_0 such that $\int s^-(x, Q_0) dx = 0$
- Total momentum sum rule satisfied by rescaling gluon to balance any change in $\int x s^+$
 - Gluon sea is large, uncertainty is also large
 - Strange sea is small
 - \Rightarrow gluon uncertainty can handle small perturbation (< 1%)



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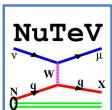


s^+, s^- fit results:

Parameter	Value
m_c	1.20 GeV (fixed)
ϵ	0.60 (fixed)
κ^+	0.551 ± 0.126
κ^-	(-0.881 ± 0.567) × 10⁻²
α^+	1.11 ± 0.69
α^-	6.31 ± 4.06
γ^+	0.072 ± 0.064
γ^-	-0.102 ± 0.080
B_c	0.099 (fixed)

$$\eta_s = \frac{\int_0^1 x s^+(x) dx}{\int_0^1 [\bar{u}(x) + \bar{d}(x)] dx}$$

η_s	S^-	Systematic
0.0612	0.00196	central value
0.0011	0.00046	statistics
0.0026	0.00034	ν π-K model
0.0019	0.00025	$\bar{\nu}$ π-K model
0.0020	0.00004	μ spectrometer p scale (1%)
0.0014	0.00008	hadron energy scale (0.5%)
0.0018	0.00005	R_L in table model (20%)
0.0026	0.00001	table extraction MC statistics
0.0030	0.00012	μ range out energy (2.5%)
0.0006	0.00005	ν , $\bar{\nu}$ relative normalization
0.0060	0.00045	total systematics
0.0022	0.00002	$\Delta m_c = 0.10$
0.0020	0.00021	$\Delta \epsilon_{C-S} = 0.3$
0.0101	0.00111	$\Delta B_c = 0.012$
0.0068	0.00046	CTEQ6 PDF uncertainties
0.0007	0.00038	Nuclear corrections
0.0126	0.00128	total external measurement

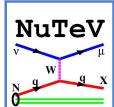
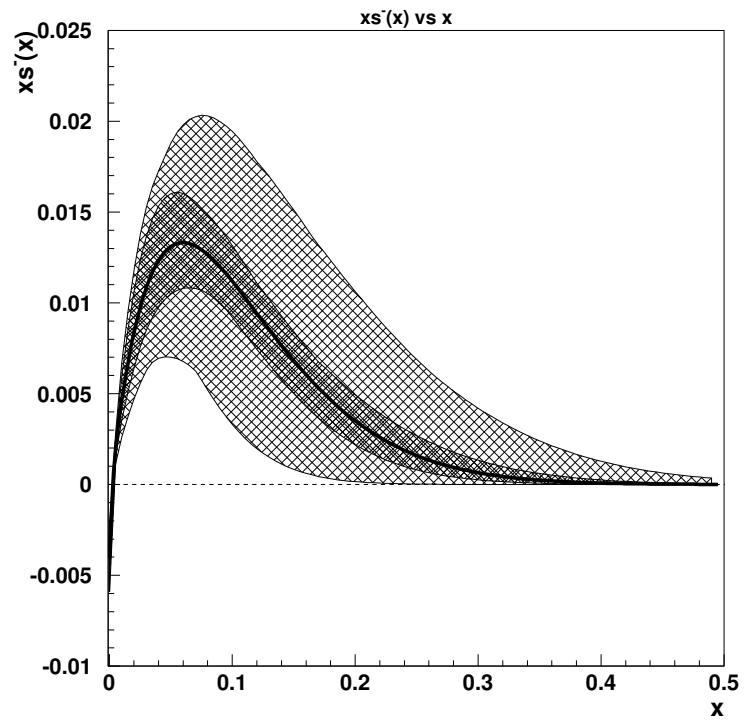


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s^+, s^- asymmetry

- $\chi^2 = 38.2$ out of 37.8 DoF
- s^- prefers to satisfy sum rule by spiking negative at low x
- Crossing point at $x_0=0.004$
- gluon sea only needs 0.07% change
- Asymmetry still consistent with previous two fits

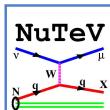


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κ, α, m_c fit

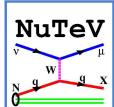
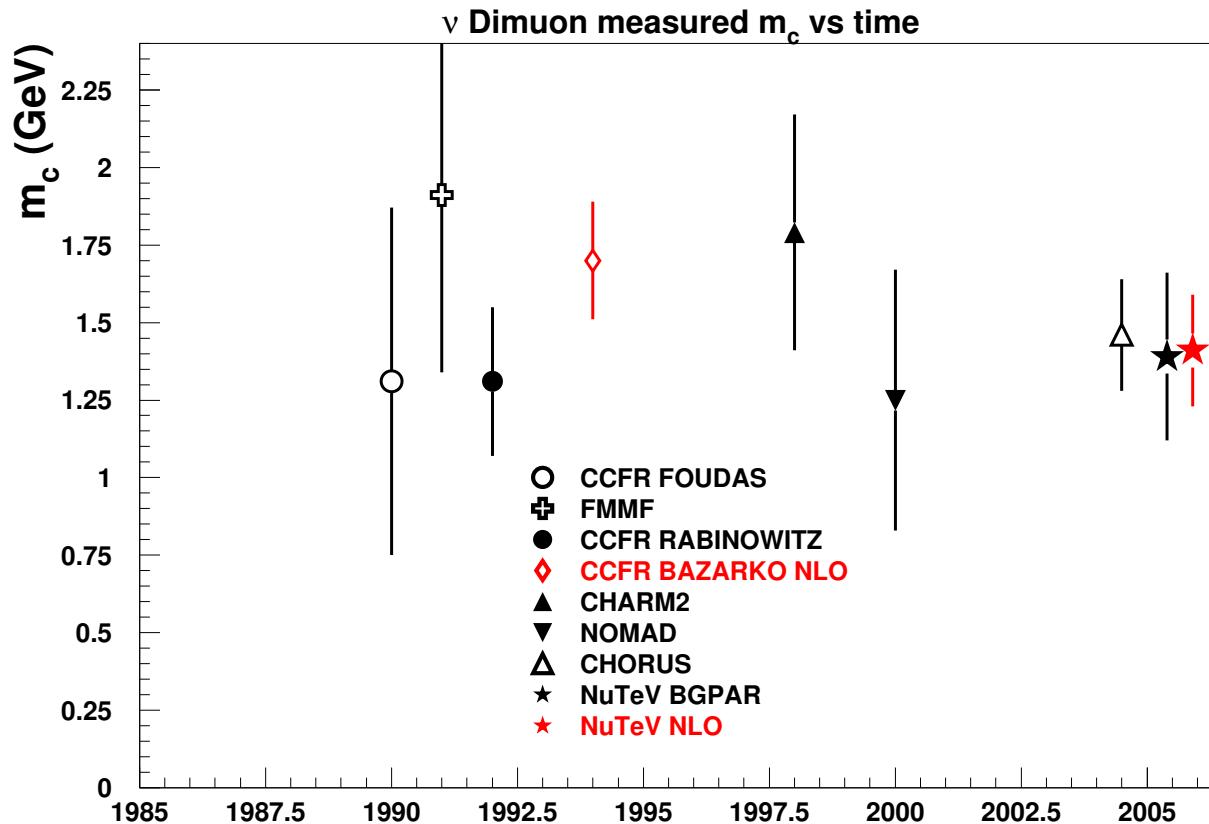
Description	m_c (GeV)	κ	$\bar{\kappa}$	α	$\bar{\alpha}$	S^-
Central value	1.409	0.436	0.348	0.76	0.90	0.00203
Statistical error	0.010	0.035	0.032	0.66	0.68	0.00057
$\nu \pi\text{-K}$ (15%)	0.035	0.008	0.006	0.33	0.03	0.00040
$\bar{\nu} \pi\text{-K}$ (21%)	0.044	0.002	0.016	0.01	0.07	0.00035
Emuff scale (1%)	0.011	0.006	0.016	0.18	0.02	0.00001
Had energy scale (0.5%)	0.027	0.005	0.007	0.12	0.01	0.00008
R_L (20%)	0.038	0.011	0.018	0.06	0.02	0.00008
Emu2 rangeout	0.03	0.010	0.020	0.28	0.01	0.00010
Flux norm	0.002	0.002	0.006	0.07	0.01	0.00001
All Table Systematics	0.079	0.017	0.036	0.49	0.10	0.00055
Fragmentation ϵ	0.064	0.003	0.004	0.19	0.01	0.00021
B_c	0.107	0.043	0.050	1.13	0.05	0.00119
All External M'mnt	0.124	0.042	0.050	1.15	0.05	0.00121
Total Systematics	0.147	0.046	0.061	1.25	0.11	0.00133



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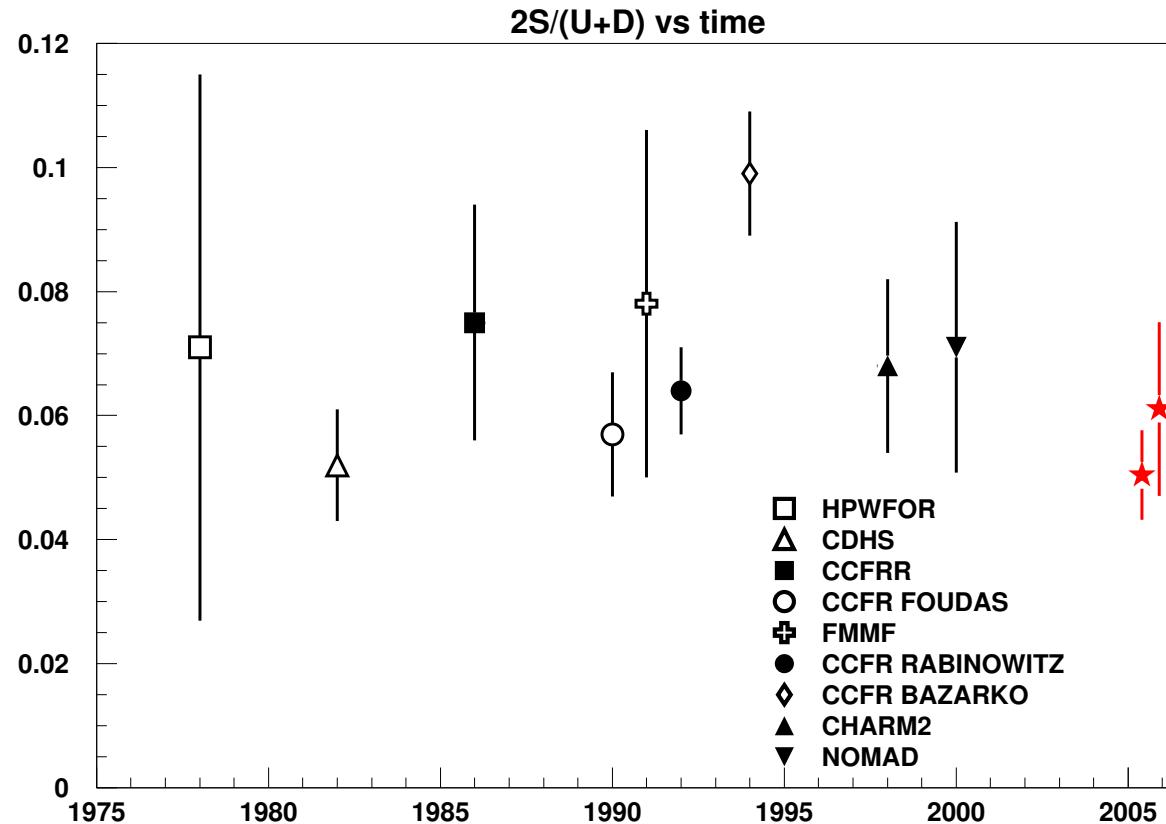
Charm masses through the ages...



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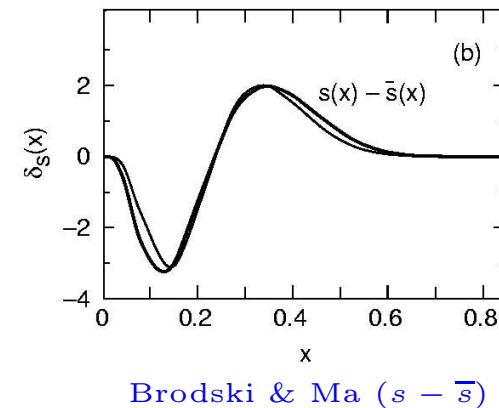
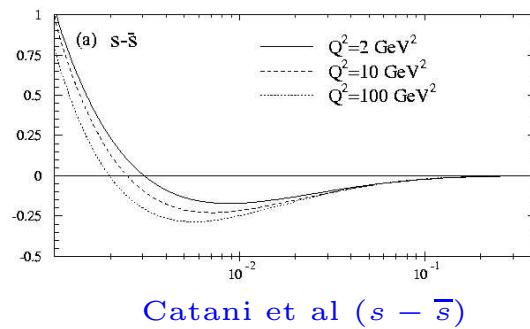
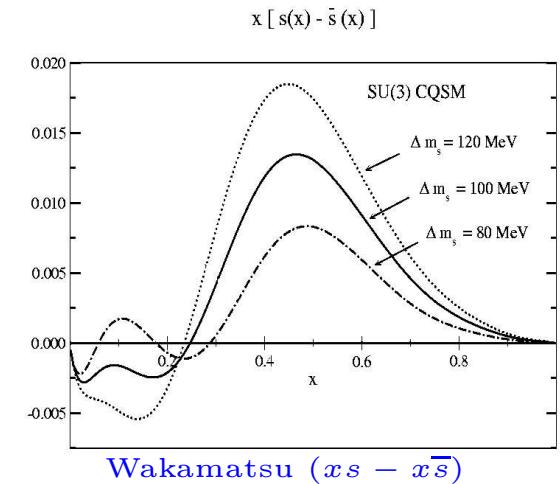
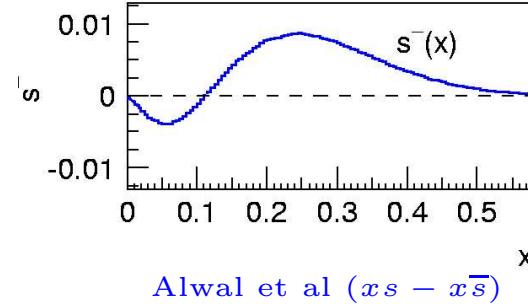
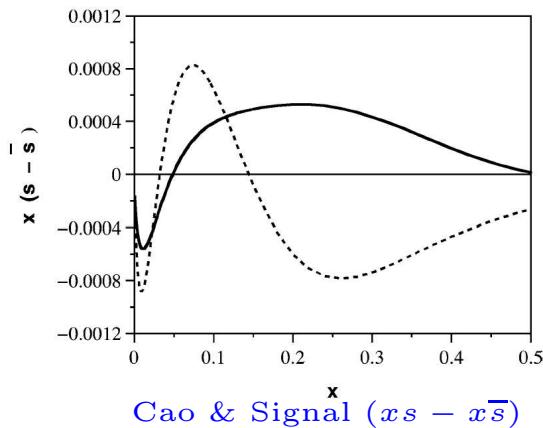
η_s through the ages...



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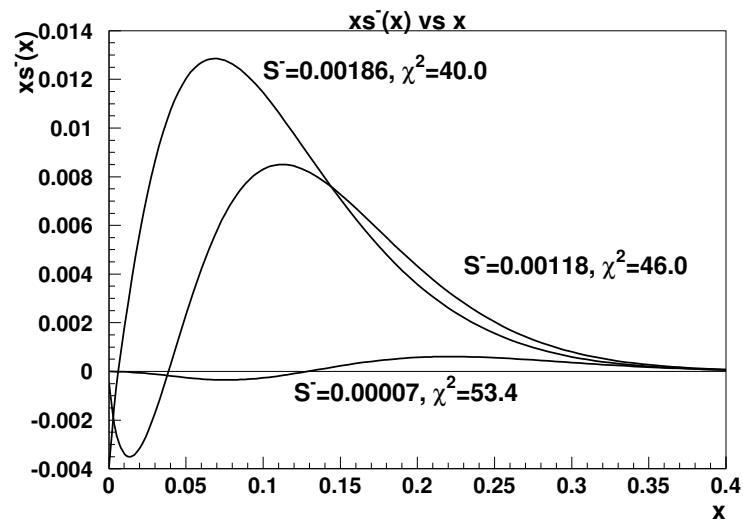
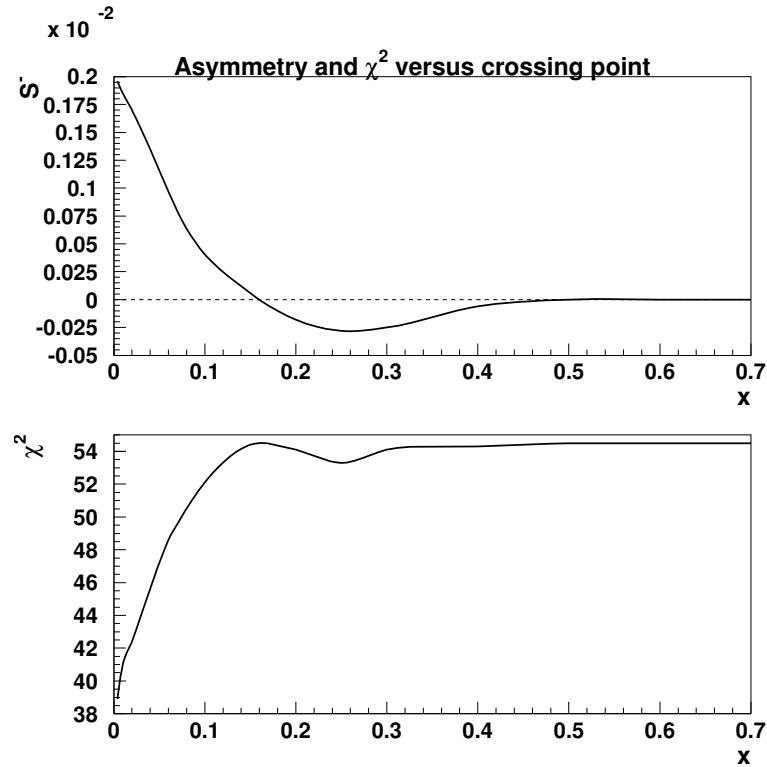
A Reminder of the Pantheon of Asymmetries



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So we look at the asymmetry vs. crossing point...



$$s^-(x, Q_0) = s^+(x) \tanh \left[\kappa^- (1-x)^{\alpha^-} x^{\gamma^-} \left(1 - \frac{x}{x_0} \right) \right]$$

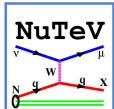


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Conclusion!

- We have measured the strange asymmetry to be positive
 - First complete NLO analysis
 - Sign selected beam
 - Various schemes, including proper evolution, QCD sum rules satisfied
 - Modern nuclear corrections
- Have measured charm mass
- Found asymmetry difficult to accomodate with x_0 at high x



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The NuTeV Collaboration:

T. Adams⁴, A. Alton⁴, S. Avvakumov⁸, L. de Barbaro⁵, P. de Barbaro⁸,
R. H. Bernstein³, A. Bodek⁸, T. Bolton⁴, J. Brau⁶, D. Buchholz⁵, H. Budd⁸,
L. Bugel³, J. Conrad², R. B. Drucker⁶, B. T. Fleming², R. Frey⁶,
J. A. Formaggio², J. Goldman⁴, M. Goncharov⁴, D. A. Harris⁸, R. A. Johnson¹,
J. H. Kim², S. Koutsoliotas², M. J. Lamm³, W. Marsh³, D. Mason⁶, J. McDonald⁷,
K. S. McFarland^{8,3}, C. McNulty², D. Naples⁷, P. Nienaber³, V. Radescu⁷,
A. Romosan², W. K. Sakamoto⁸, H. Schellmann⁵, M. H. Shaevitz², P. Spentzouris²,
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⁵Northwestern University, Evanston, IL

⁶University of Oregon, Eugene, OR

⁷University of Pittsburgh, Pittsburgh, PA

⁸University of Rochester, Rochester, NY



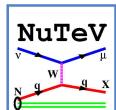
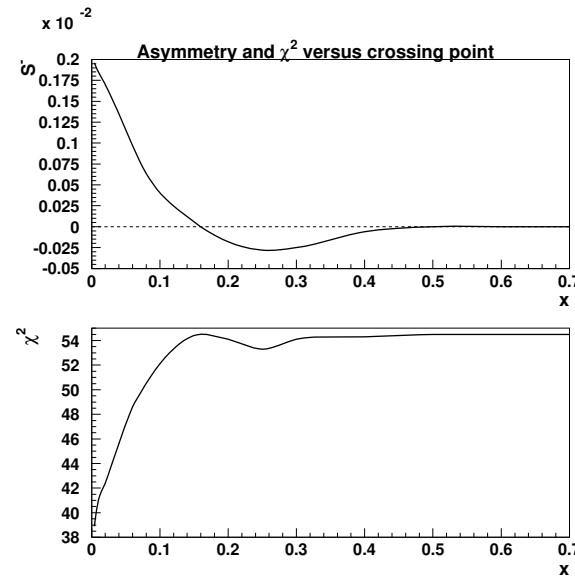
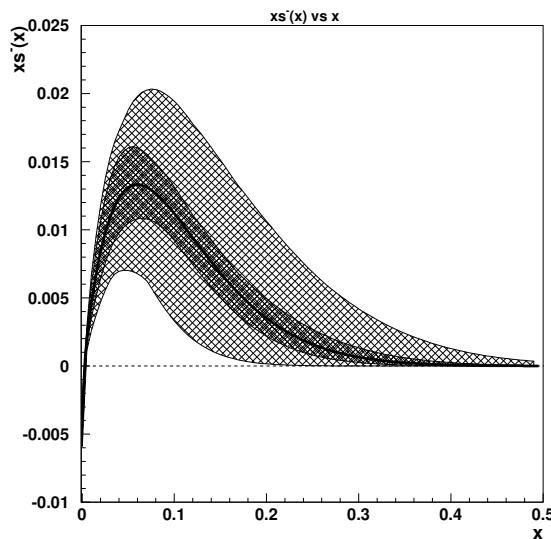
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Summary:

$$S^- = +0.00196 \pm_{\text{(stat)}} 0.00046 \pm_{\text{(syst)}} 0.00045 \pm_{\text{(external)}} 0.00128$$

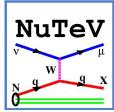
$$m_c = 1.41 \pm_{\text{(stat)}} 0.10 \pm_{\text{(syst)}} 0.08 \pm_{\text{(external)}} 0.12 \text{ GeV}/c^2$$



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Extra Slides



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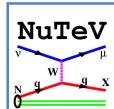
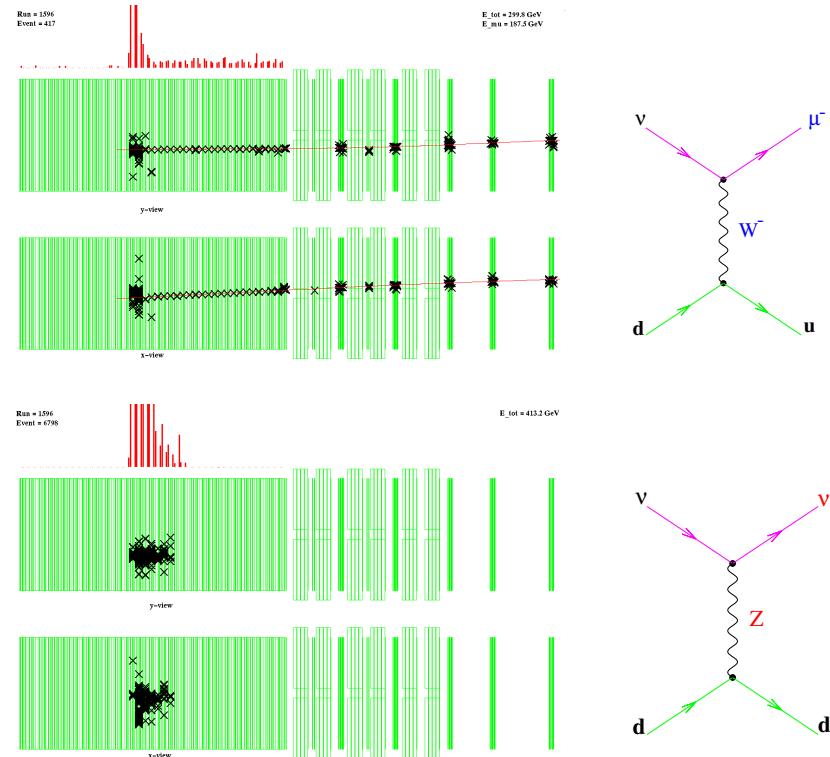


NuTeV's flagship measurement: $\sin^2 \theta_W$

Paschos Wolfenstein Relation:

$$R^- = \frac{\sigma_{NC}^\nu - \sigma_{NC}^{\bar{\nu}}}{\sigma_{CC}^\nu - \sigma_{CC}^{\bar{\nu}}} = \rho^2 \left(\frac{1}{2} + \sin^2 \theta_W \right)$$

- Separate ν & $\bar{\nu}$ beams req'd
- Experimentally measure long (CC) vs short (NC) events
- Insensitive to sea quark uncert.
- But assumes symmetric s, c seas



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Strange Asymmetry?

- QCD requires $\int(s - \bar{s}) dx = 0$
- No restriction on $\int x (s - \bar{s}) dx$

Allowing for s asymmetry:

$$R^- \simeq \frac{1}{2} - \sin^2 \theta_W - \left(\frac{1}{2} - \frac{7}{6} \sin^2 \theta_W \right) \frac{S^-}{Q^-}$$

where:



$$Q^- \equiv \int_0^1 x \frac{u_v(x) + d_v(x)}{2} dx$$

$$S^- \equiv \int_0^1 x [s(x) - \bar{s}(x)] dx$$

$S^- \sim 0.0068$ brings NuTeV in agreement with S.M.

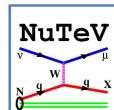
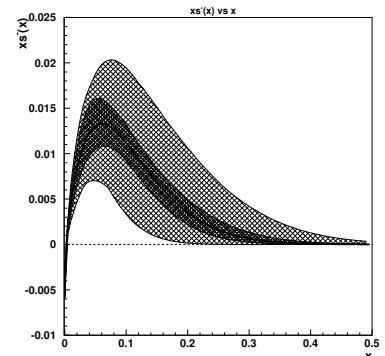


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Strange Asymmetry and NuTeV $\sin^2 \theta_W$

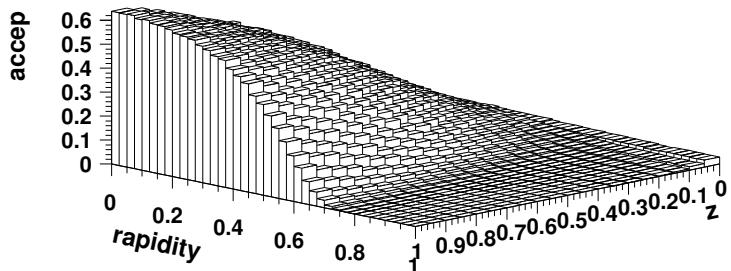
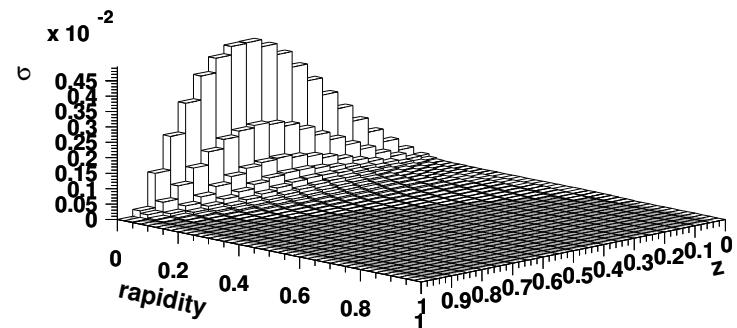
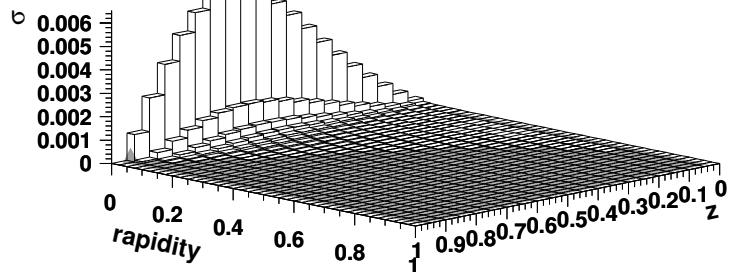
- NuTeV measures $R^- = \frac{\sigma_{NC}^\nu - \sigma_{\bar{NC}}^{\bar{\nu}}}{\sigma_{CC}^\nu - \sigma_{CC}^{\bar{\nu}}}$
- From that $\sin^2 \theta_W$ is extracted
 - Insensitive to sea quark uncertainties
 - But assumes symmetric strange sea
- QCD requires $\int (s - \bar{s}) dx = 0$
- No QCD restriction on $S^- \equiv \int x (s - \bar{s}) dx$
- R^- correction for asymmetric strange sea is proportional to S^-
- $S^- \sim 0.0068$ required for agreement with S.M.



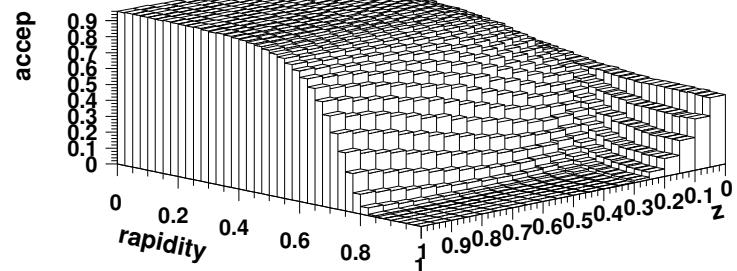
David A. Mason
FNAL: March 21, 2006



DISCO and $E_{\mu 2} > 5$ GeV acceptance



$E_\nu = 88$ GeV



$E_\nu = 247$ GeV



David A. Mason
FNAL: March 21, 2006



What about comparing S^- ?

- Only done by Foudas et al (CCFR) \implies
- And Bazarko, shape only
- Both found s consistent with \bar{s}
- But also didn't have sign selected beam

